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COMBINATION FRAMED MIDSHIP SECTION
OPERATION MANUAL

by

Donald Liu

Charles E. Roth, III

(COMPUTOR APPLICATIONS TO THE STRUCTURAL DESIGN OF A COMBINATION FRAMED MIDSHIP SECTION - VOLUME II)

Thesis
R7793
v.2

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COMBINATION FRAMED MIDSHIP SECTION

OPERATION MANUAL

BY:

DONALD LIU

CHARLES E. ROTH III

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~~Thesis~~
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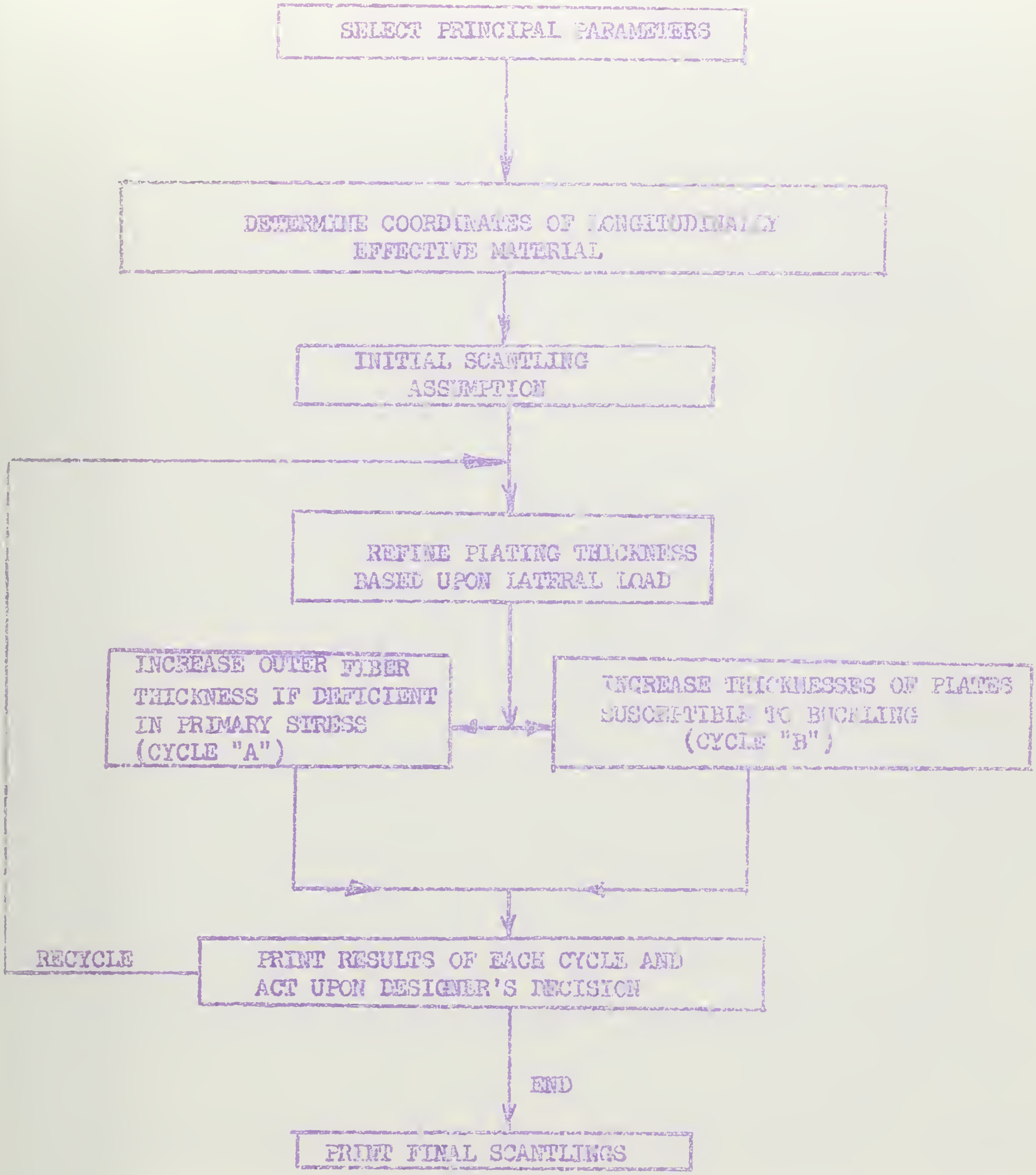
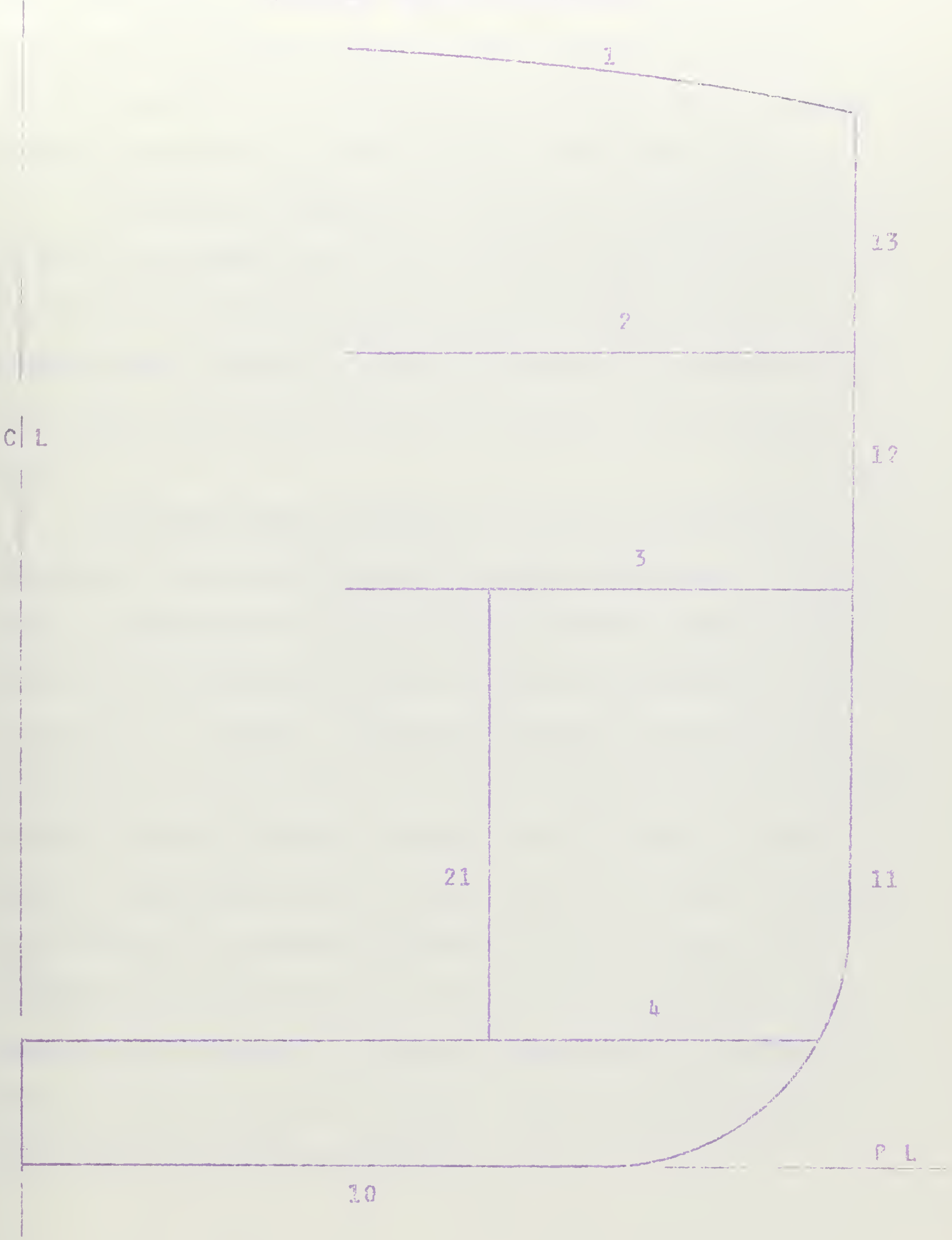
SCHEMATIC REPRESENTATION OF DESIGN PROCESS


SELECT PRINCIPAL PARAMETERS
DETERMINE COORDINATES OF LONGITUDINALLY EFFECTIVE MATERIAL
INITIAL SCANTLING ASSUMPTION
REFINE PLATING THICKNESS BASED UPON LATERAL LOAD
INCREASE OUTER FIBER THICKNESS IF DEFICIENT IN PRIMARY STRESS (CYCLE "A")
INCREASE THICKNESSES OF PLATES SUSCEPTIBLE TO BUCKLING (CYCLE "B")
RECYCLE
PRINT RESULTS OF EACH CYCLE AND ACT UPON DESIGNER'S DECISION
END
PRINT FINAL SCANTLINGS

TYPICAL MIDSHIP SECTION



An attempt has been made to devise a numbering index that is clear to the designer, general enough to fit any geometry, and yet compatible with efficient computer usage. Familiarity with the internal operation of the program is not necessary, but by scanning the manual, the user will gain confidence in the unseen operation.

The seams of plating are numbered in ascending order from the keel plate center up the shell side; and continuing from the 1st deck to the inner bottom, if that exists; and finally through the bulkhead seams. The ship has been broken down into sections, and the longitudinals within those sections are indexed in the following manner.

The bottom shell is labeled as section #10, the first longitudinal being indexed as (10,1) and continuing through the total number of longitudinals for that section. The next section up the shell side is labeled section #11, the next is #12, continuing until the main deck is reached. The decks are labeled as section #1 for the main deck, section #2 for the second, continuing for all the decks, the inner bottom is indexed as one more than the number of decks. Again the longitudinals follow the same logic as the side. Therefore, (3,7) signifies the seventh longitudinal on the third deck. The bulkheads begin with the index of "21" for the first bulkhead, and continue for all bulkheads. Again the longitudinals are labeled as before. Before operating the program, a sketch should be prepared so any confusion will be alleviated.

STEP 1.

The actual operation begins with the loading of the program into the computer core as shown below.

```
LOADGO MN STF PIT TAP SUB CYC BUK END
```

STEP 2.

Presently the program is set to design a merchant ship, and all principal dimensions are arranged to fit A.B.S. ships. The input data existing now can be modified. Thecomputer will print a comment showing what symbols can be changed at each interval, and the changes may be made.

This is done by setting the symbol representing the quantity to be changed equal to the new value. For example, (LBP = 500) means that the length between perpendiculars will be 500 ft.

The information telling which sections are to be transversely framed is contained in a vector called TRANSV. If sections 1, 2, and 11 are to be transversely framed, the array is filled by typing "TRANSV(1) = 1, 2, 11". Any section number may be included on the right side of the equal sign.

Longitudinal bulkhead information is contained in a two-dimensional array called "BHD (I, J)". The rows (I) are the sequence of bulkhead (i.e., first, second) while the columns (J), contain data describing the location of the bulkhead. If the operator wanted two bulkheads, and the second were 10 ft. from the center line, lying between decks #1 and #3, he would type "BHD(2,1) = 10, 1, 3."

An inner bottom is provided by typing; IB = YES; if no inner bottom is desired then type; IB = NO. As each interval of data input is finished, the operator must type an asterisk (*). Reference to the sample session at the console will clear up any confusion found in the manner in which data is introduced.

At two intervals in the design of the coordinate system, the operator may stop the program to look at the scantlings. This provision is only to be used if the coordinate system is being revised, and provides a quick look at the locations. In any event, they will be printed out at the end of the program, so it is best to skip them now.

Control is removed from the operator until the end of each cycle, whereupon he can make his decision as to which set of thicknesses to use for the next cycle; or if the design is satisfactory, he may choose the final thicknesses and stop. The final scantling design is printed and the program is ended.

SAMPLE SESSION AT CONSOLE

```
loadgo mn plt stf tap cyc buk end sub
W 2021.7
EXECUTION.


                THE VALUES BELOW MAY BE ALTERED NOW


            LBP,B,D,H,NDKS,HEEL,DDRISE,FRSP,WEBSP,SIGMAY,F,NBHDS
            YBASIC,DBASIC,ABASIC,SBASIC,CX,CB,IB,TRANSV(1)



lbp=550,b=75,d=39.3,h=27.5,cx=.98,cb=.67,frsp=30,websp=30,ndks=
nbhds=0,ib=$yes$,
transv(1)=1,2,3,4,10,11,12*


                THE VALUES BELOW MAY BE ALTERED NOW


            SIGLIM,BM,R,HATCHO,CVK,ZREQ



cvk=3.93*

 FOR STIFFENERS,TYPE 1-NONE,TYPE 0

0

FOR SEAMS,TYPE 1,NONE,TYPE 0

 0
```

```
OK
OK
OK
OK
1
2
3
4
5
5
6
7
OKT
OKT
OKT
OKT
2
OK1
OKT
3
4
5
5
6
7
OKT
HIT RETURN FOR RESULTS OF THIS CYCLE
```

```
1
                                           RESULTS OF CYCLE NO. 1
                                           ----------------------


             S T A R T I N G                     B E N D I N G            B U C K L I N G
                                                 G O V E R N S            G O V E R N S

    NO.      T          SIGMA1                   T          SIGMA1        T          SIGMA1


          SHELL  STRAKES

     1      .676        6179.3                 .619        6507.7       .619        6571.3
     2      .451        6179.3                 .422        6507.7       .422        6571.3
     3      .483        6179.3                 .442        6507.7       .442        6571.3
     4      .504        6179.3                 .461        6507.7       .461        6571.3
     5      .524        6179.3                 .479        6507.7       .479        6571.3
     6      .542        6138.7                 .496        6468.0       .496        6531.4
     7      .542        5277.6                 .497        5629.0       .497        5687.7
     8      .530        3534.0                 .490        3930.0       .490        3979.0
     9      .557        1412.8                 .619        1863.0       .619        1900.3
    10      .524         731.5                 .579         226.4       .579         201.2
    11      .487        2875.8                 .536        2315.9       .536        2302.4
    12      .447        5020.1                 .428        4405.3       .488        4403.7
    13      .404        7164.4                 .437        6494.8       .437        6505.0
    14      .404        9308.7                 .404        8584.3       .404        8606.3
    15      .404       11453.0                 .404       10673.7       .426       10707.7
    16      .404       13597.3                 .404       12763.2       .428       12809.0
    17      .404       15889.5                 .425       14996.7       .429       15055.2
    18      .404       18181.6                 .446       17230.2       .431       17301.4
  NEXT PAGE
```

			BENDING		BUCKLING	
	DECK NO. 1					
19	.286	18350.7	.329	17394.9	.315	17467.1
20	.288	18456.4	.331	17497.1	.315	17570.7
21	.290	18547.1	.332	17586.4	.318	17659.6
22	.291	18623.0	.333	17660.3	.319	17733.9
23	.292	18683.9	.334	17719.6	.320	17793.6
	DECK NO. 2					
24	.345	14494.2	.352	13637.1	.352	13687.9
25	.313	14494.2	.317	13637.1	.341	13687.9
26	.313	14494.2	.317	13637.1	.341	13687.9
27	.313	14494.2	.317	13637.1	.341	13687.9
28	.313	14494.2	.317	13637.1	.341	13687.9
	DECK NO. 3					
29	.296	10806.9	.304	10044.1	.304	10074.5
30	.281	10806.9	.287	10044.1	.287	10074.5
31	.281	10806.9	.287	10044.1	.287	10074.5
32	.281	10806.9	.287	10044.1	.287	10074.5
33	.281	10806.9	.287	10044.1	.287	10074.5
	INNER BOTTOM STRAKES					
34	.489	3743.2	.457	4133.9	.457	4184.0
35	.489	3743.2	.457	4133.9	.457	4184.0
36	.489	3743.2	.457	4133.9	.457	4184.0
37	.489	3743.2	.457	4133.9	.457	4184.0
38	.489	3743.2	.457	4133.9	.457	4184.0
39	.489	3743.2	.457	4133.9	.457	4184.0
40	.489	3743.2	.457	4133.9	.457	4184.0
41	.489	3743.2	.457	4133.9	.457	4184.0

NEXT PAGE

```
                                   B E N D I N G          B U C K L I N G
WT. OF EFFECTIVE MATL                 6.38 T/FT.             6.15 T/FT.

MAX. DIFF.
IN BENDING STRESS                   -882.2 PSI               93.3 PSI
(SIGMA1-LIMIT STRESS)

MAX. DIFF.
IN BUCKLING STRESS                   497.4 PSI             5209.6 PSI
(ACTUAL-ALLOWED)

N.A.(ABOVE KEEL)                     16.98  FT.             16.83  FT.

SECTION MODULUS
     KEEL                       121076.7 FT.SQ.IN.     116201.1 FT.SQ.IN.
     DECK                        55197.1 FT.SQ.IN.      62711.7 FT.SQ.IN.

LIMITING PRIMARY STRESS          17709.03 PSI

REQUIRED SECTION MODULUS         43162.91FT.SQ.IN.



TYPE:

     1      TO CYCLE AGAIN WITH THICKNESS FROM BENDING
     2      TO CYCLE AGAIN WITH THICKNESS FROM BUCKLING
     3      TO STOP WITH THICKNESS FROM BENDING
     4      TO STOP WITH THICKNESS FROM BUCKLING
1
```

SEAMS

NO.	X COORD	Y COORD.	THICKNESS	PLT WIDTH
SEAMS ON SHELL				
1	2.22	0.	.52	2.22
2	7.60	0.	.42	5.38
3	12.97	0.	.46	5.38
4	18.35	0.	.40	5.38
5	23.75	0.	.48	5.38
6	29.11	.10	.50	5.38
7	33.96	2.26	.50	5.38
8	36.97	6.64	.49	5.38
9	37.50	11.96	.52	5.38
10	37.50	17.34	.53	5.38
11	37.50	22.72	.54	5.38
12	37.50	28.09	.49	5.38
13	37.50	33.47	.44	5.38
14	37.50	38.85	.40	5.38
15	37.50	44.23	.40	5.38
16	37.50	49.61	.40	5.38
17	37.50	55.36	.47	5.75
18	37.50	61.11	.46	5.75
DECK NO.1				
19	31.76	61.54	.39	5.75
20	27.57	61.80	.39	4.20
21	23.38	62.03	.39	4.20
22	19.19	62.22	.39	4.20
23	15.00	62.37	.39	4.20

NO	X COORD.	Y COORD.	THICKNESS	PLT WIDTH
DECK NO.2				
24	31.75	51.86	.35	5.75
25	27.56	51.86	.32	4.19
26	23.38	51.86	.32	4.19
27	19.19	51.86	.32	4.19
28	15.00	51.86	.32	4.19
DECK NO.3				
29	31.75	42.61	.30	5.75
30	27.56	42.61	.29	4.19
31	23.38	42.61	.29	4.19
32	19.19	42.61	.29	4.19
33	15.00	42.61	.29	4.19
INNER BOTTOM				
34	2.22	6.11	.46	[illegible]
35	7.24	6.11	[illegible]	5.02
36	12.25	6.11	.46	5.02
37	17.28	[illegible]	.46	5.02
38	22.30	6.11	.46	5.02
39	27.32	6.11	.46	5.02
40	[illegible]	6.11	.46	5.02
41	[illegible]	6.11	.46	[illegible]

LONGITUDINAL STIFFENERS

LONG'LS ON BOTTOM SHELL UP TO INNER BOTTOM,(SPACING=29.5 IN.)

NO.	X COORD.	Y COORD.	SCANTLINGS	SECTION MODULUS
1	2.46	0	15.66X15.22X1.307 T	50.942
2	4.91	0.	14.85X14.44X1.239 T	43.439
3	7.37	0	15.21X14.79X1.269 T	46.675
4	9.83	0	15.57X15.14X1.299 T	50.069
5	12.28	0.	15.84X15.40X1.322 T	52.719
6	14.74	0	16.20X15.75X1.352 T	56.395
7	17.20	0.	16.38X15.92X1.367 T	58.296
8	19.66	0.	16.65X16.19X1.389 T	61.227
9	22.11	0.	16.83X16.36X1.404 T	63.23[illegible]
10	24.57	0.	16.92X16.49X1.412 T	64.258
11	27.03	0	17.03X16.54X1.420 T	65.285
12	28.75	.16	17.10X16.62X1.427 T	66.327
13	31.09	.90	17.10X16.62X1.427 T	66.327
14	33.16	2.20	17.10X16.62X1.427 T	66.327
15	34.85	3.97	17.10X16.62X1.427 T	66.327

```
NO          X COORD.          Y COORD.          SCANTLINGS            SECTION MODULUS


 INNER BOTTOM,(SPACING=29.5 IN.)

 24            2.46             6.11      16.11X15.66X1.344 T              55.461
 25            4.91             6.11      16.11X15.66X1.344 T              55.461
 26            7.37             6.11      16.11X15.66X1.344 T              55.461
 27            9.83             6.11      16.11X15.66X1.344 T              55.461
 28           12.28             6.11      16.11X15.66X1.344 T              55.461
 29           14.74             6.11      16.11X15.66X1.344 T              55.461
 30           17.20             6.11      16.11X15.66X1.344 T              55.461
 31           19.66             6.11      16.11X15.66X1.344 T              55.461
 32           22.11             6.11      16.11X15.66X1.344 T              55.461
 33           24.57             6.11      16.11X15.66X1.344 T              55.461
 34           27.03             6.11      16.11X15.66X1.344 T              55.461
 35           29.48             6.11      16.11X15.66X1.344 T              55.461
 36           31.94             6.11      16.11X15.66X1.344 T              55.461
 37           34.36             6.11      16.11X15.66X1.344 T              55.461
```

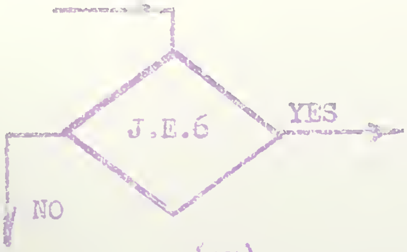
```
NO            X COORD            Y COORD        SCANTLINGS          SECTION MODULUS


SECTION NO  11 ,UP TO DECK NO. 3 IS TRANSVERSELY FRAMED


SECTION NO. 12 ,UP TO DECK NO. 2 IS TRANSVERSELY FRAMED


SECTION NO. 13 ,UP TO DECK NO. 1 IS TRANSVERSELY FRAMED


DECK NO.1(SPACING=33.3 IN.)

 16              34.69              61.35      10.26X 9.97X
 17              31.88              61.53      10.26X 9.97X
 18              29.06              61.71      10.26X 9.97X
 19              26.25              61.88      10.26X 9.97X
 20              23.44              62.05      10.26X 9.97X
 21              20.63              62.16      10.26X 9.97X
 22              17.81              62.27      10.26X 9.97X
 23              15.00              62.37      10.26X 9.97X


DECK NO.2 IS TRANSVERSELY FRAMED


DECK NO 3 IS TRANSVERSELY FRAMED
```

DESCRIPTION OF INTERNAL OPERATION

AND

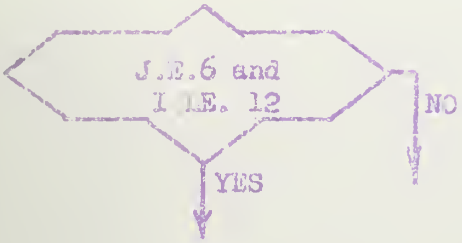
FLOW CHARTS

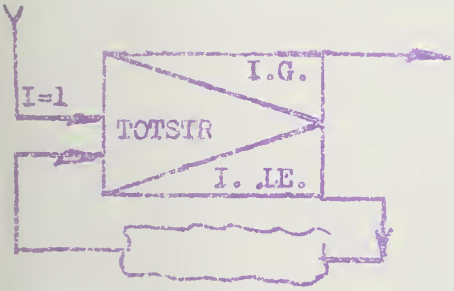
FLOW CHART SYMBOLS



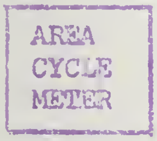
A decision branch
("whenever" statement)

(or)

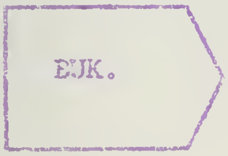




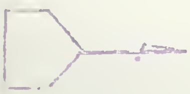
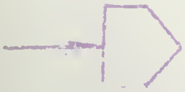
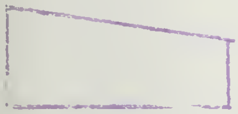
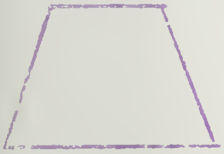
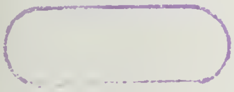
An iteration; for example, the 'through loop' where I is initially set to 1 and the iteration is performed until I is greater than TOTSTR.



The enclosed values are calculated.



Subroutine (BUK) is executed.

	Continuation from previous page
	Continuation to next page
	Print out of data
	Read in Data
	Beginning or end of each subroutine

(MN.) is the input and calling program that executes the subroutines and contains all of the necessary input data for the operation of the program.

(MN.) first clears all simulated tapes of any existing data computed from previous runs and then sets the values for the following:

Young's modulus, length between perpendiculars, beam, depth, draft, number of decks, heel angle, deadrise, frame spacing, web spacing, midship section coefficient, height of center vertical keel, block coefficient, yield stress, number of bulkheads, the depth, area, height of neutral axis, moment of inertia and section modulus of the basic stiffener, bending moment, limiting bending stress, bilge radius, number of longitudinal bulkheads in the midship half section, and the width of cargo hatch.

The required ship section modulus is determined according to the Load Line Regulations and is calculated by the subroutine (REQSEC.)

To change any of the above existing data, there are two program stops which permit new input data to be read into the computer. Refer to the section on program operation for further clarification of the main program.

LIST OF SYMBOLS CALCULATED IN (MN)

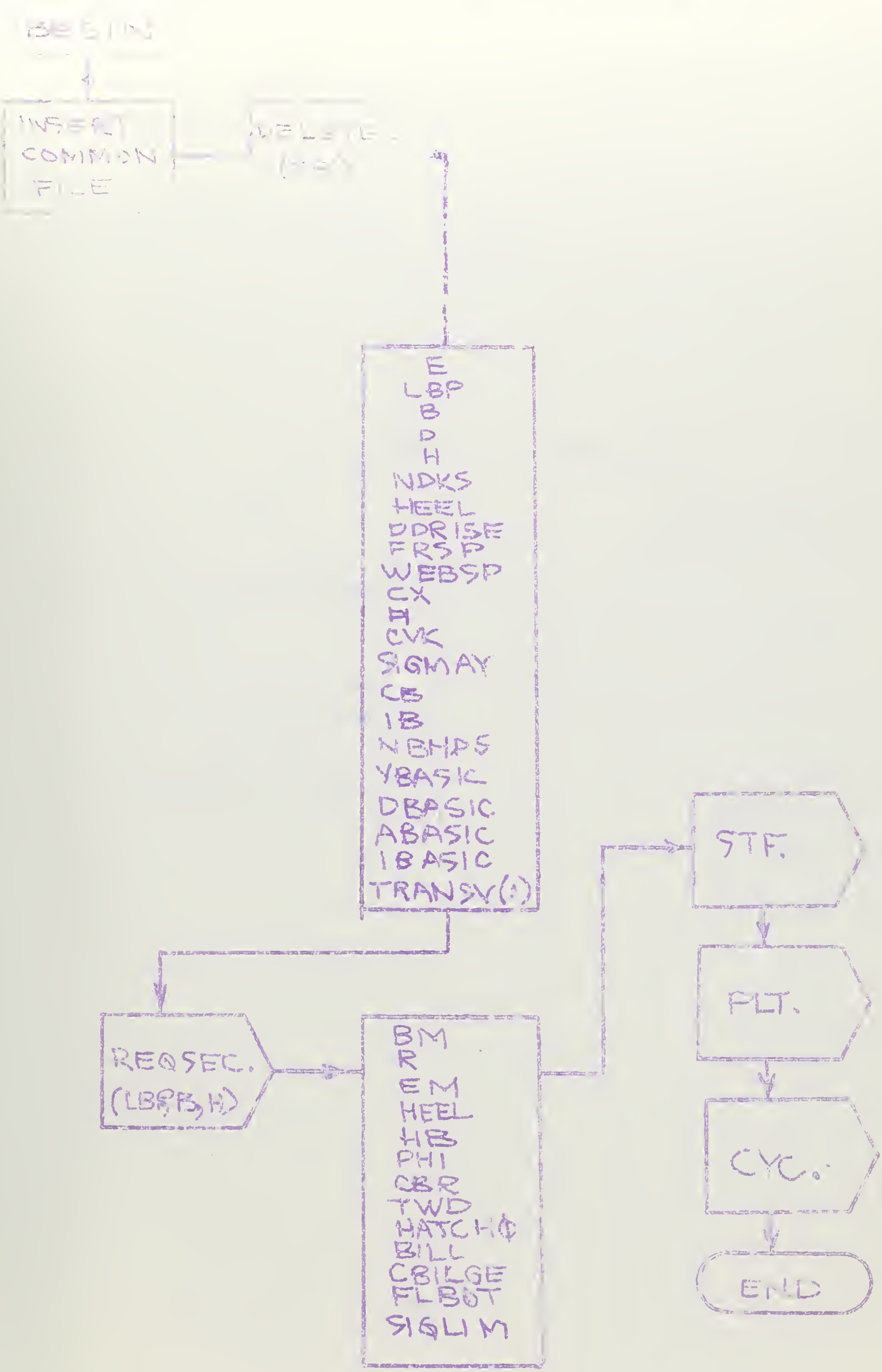
A(I)	Array of numbers from (1), Sect. 43.15 - 17(c)(5) used in calculating ZREQ.
ABASIC	Area of basic stiffener.
B	Breadth of ship.
BILL	Linear length of bilge.
BM	Bending moment of ship on wave.
CB	Block coefficient.
CBILGE	Height of bilge center above keel.
CBR	Standard camber.
CVK	Height of inner bottom.
CX	Midship coefficient.
D	Depth of ship.
DBASIC	Depth of basic stiffener.
DDRISE	Dead rise of ship hull.
E	Young's modulus.
EM	Function used in a buckling formula later in the program.
FLBOT	Length of flat portion of bottom shell.
FRSP	Nominal longitudinal spacing.
H	Draft of ship.
HATCHO	Half breadth of hatch opening.
HB	Half breadth of ship.
HEEL	Heel of ship used in calculating inclined water head
IB	Inner bottom
IBASIC	Inertia of basic stiffener

LIST OF SYMBOLS CALCULATED IN ([illegible])

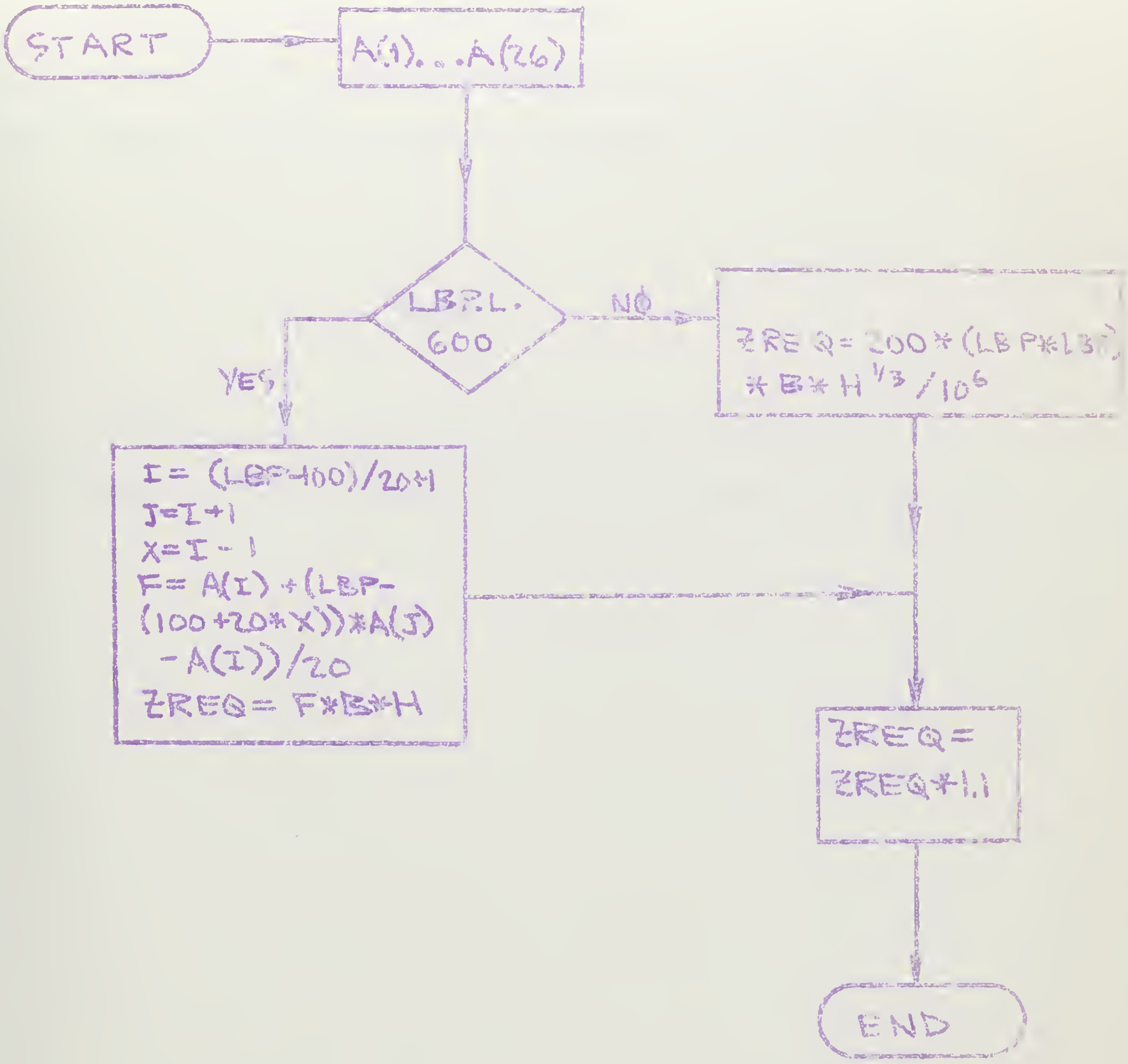
- 2 -

LBP	Length between perpendiculars.
NBHDS	Number of longitudinal bulkheads on half section.
NDKS	Number of strength decks on ship.
PHI	Angle of deadrise.
PI	3.1416
R	Bilge radius.
SIGLIM	Limiting primary bending stress.
SIGMAY	Yield strength of steel used.
TRANSV(I)	Array consisting of the numbers of sections to be transversely framed.
TWD	'Tween deck height.
WEBSP	Spacing of web frames.
YBASIC	Distance from shell to neutral axis of basic stiffener.
ZREQ	Section modulus of ship required by (1).

[illegible] SUBROUTINE


BEGIN
INSERT COMMON FILE
E
LBP
B
D
H
NDKS
HEEL
DDRISE
FRSP
WEBSP
CX
PI
CVK
SIGMAY
CB
IB
NBHDS
YBASIC
DBASIC
ABASIC
IBASIC
TRANSV(1)
REQSEC.
(LBP,B,H)
BM
R
EM
HEEL
HB
PHI
CBR
TWD
HATCHΦ
BILL
CBILGE
FLBØT
SIGLIM
STF.
PLT.
CYC.
END

INTERNAL FUNCTION REQSEL.



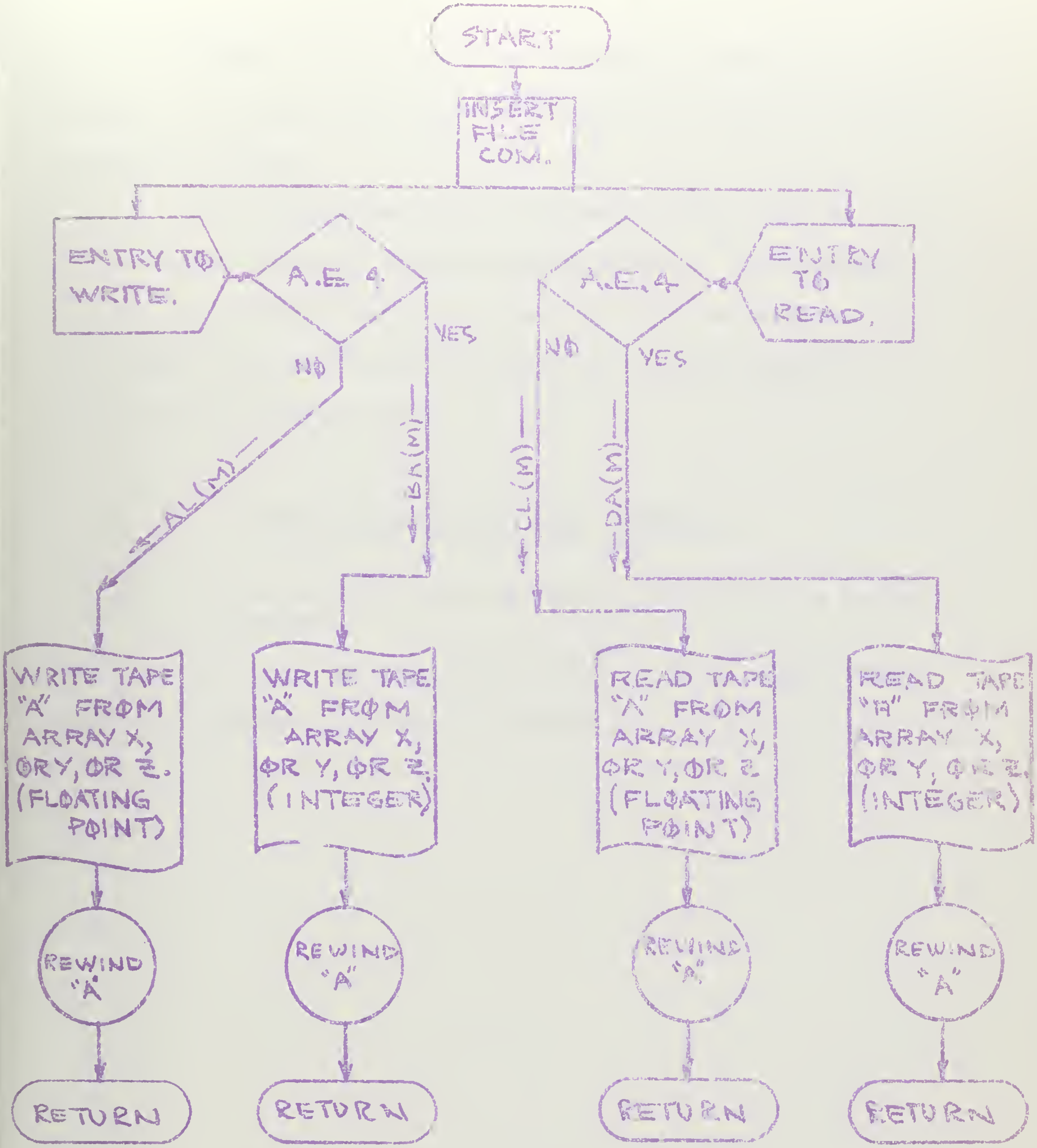
TAP.

(TAP.) is a subroutine which reads and writes PROPCO (I,J), and XLL(I,J) onto simulated tapes at various points in the program in order to conserve storage locations in the memory cell of the computer.

REQSEC.

(REQSEC.) is an internal function which calculates the required midship section modulus according to the Load Line Regulations.

{EXTERNAL FUNCTION (A,M)}


START
INSERT FILE COM.
ENTRY TO WRITE.
A.E. 4
NO
YES
AL(M)
BR(M)
A.E. 4
ENTRY TO READ.
NO
YES
CL.(M)
DA(M)
WRITE TAPE "A" FROM ARRAY X, OR Y, OR Z. (FLOATING POINT)
WRITE TAPE "A" FROM ARRAY X, OR Y, OR Z. (INTEGER)
READ TAPE "A" FROM ARRAY X, OR Y, OR Z (FLOATING POINT)
READ TAPE "A" FROM ARRAY X, OR Y, OR Z. (INTEGER)
REWIND "A"
REWIND "A"
REWIND "A"
REWIND "A"
RETURN
RETURN
RETURN
RETURN

HEAD.

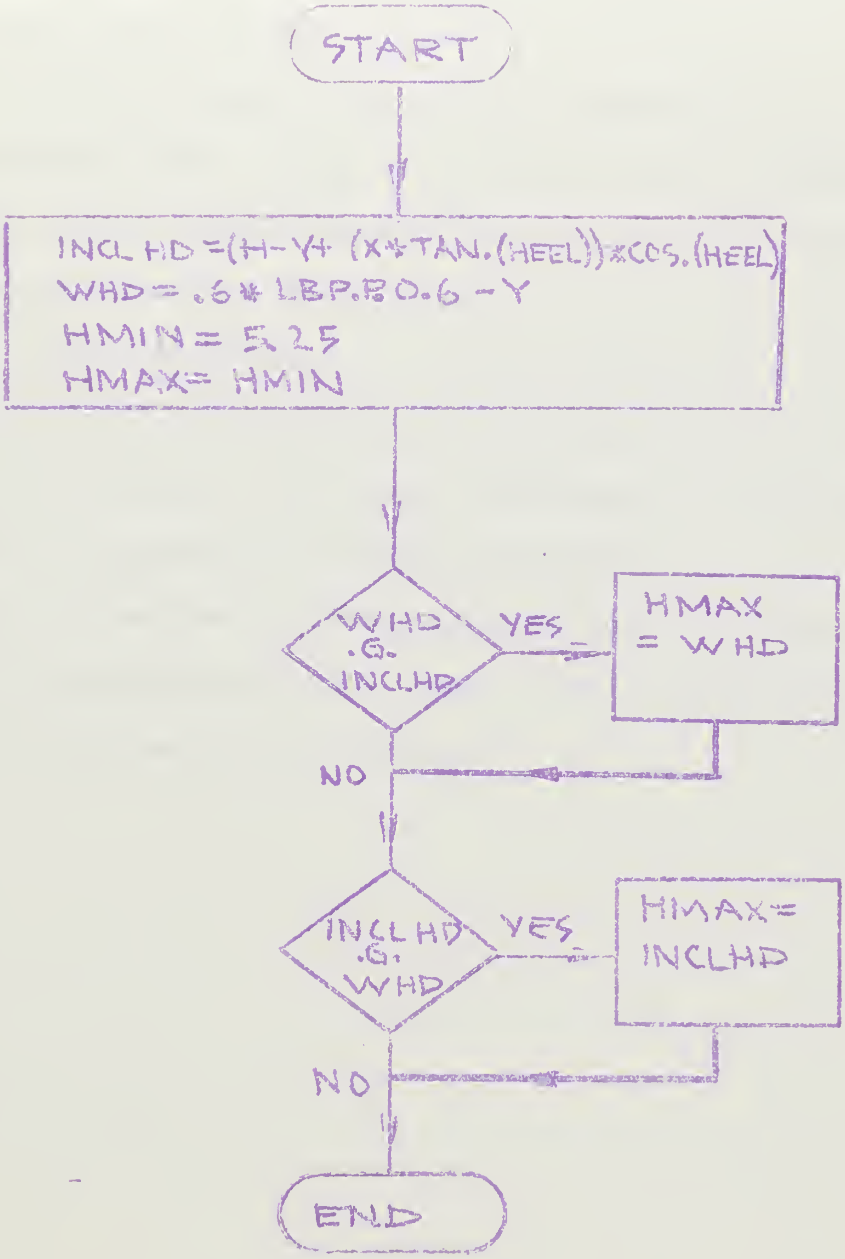
(HEAD.) is an internal function which calculates water head, using the horizontal and vertical coordinates of a point on the hull geometry as inputs.

The internal function is executed by (STF.) and (PLT.), and calculates two values of head for each coordinate: The head when the ship is heeled thirty degrees and the head in way of the wave crest. The larger of the two values is selected as the water head and it is not to be less than 5.25 feet.

LIST OF SYMBOLS CALCULATED IN (HEAD.)

INCLHD	Water head on a structural member when the ship is heeled 30 degrees.
WHD	Water head on a structural member in way of a wave crest.
HMIN	Minimum water head of 5.25 feet.

INTERNAL FUNCTION HEAD.(X,Y)



STF.

(STF.) calculates the longitudinal frame spacing in each section of the ship, determines the horizontal and vertical coordinates, measured from the keel, of the longitudinal stiffeners, and calculates the water head on each stiffener location.

The girths of each section are first computed and then a nominal longitudinal frame spacing is determined so that the longitudinal stiffeners are equally spaced on each section and as near as possible, but not exceeding, the input frame spacing.

Next, the longitudinals are located on each section based on the spacing for that section, and the XLL (horizontal) and YLL (vertical) coordinates are calculated. With these coordinates, the water heads on each stiffener are computed by the subroutine (HEAD.).

For sections that are transversely framed, thus having no longitudinals, XLL, YLL and the water heads for the sections are set equal to zero at the end of this subroutine.

SYMBOLS CALCULATED IN (STF)

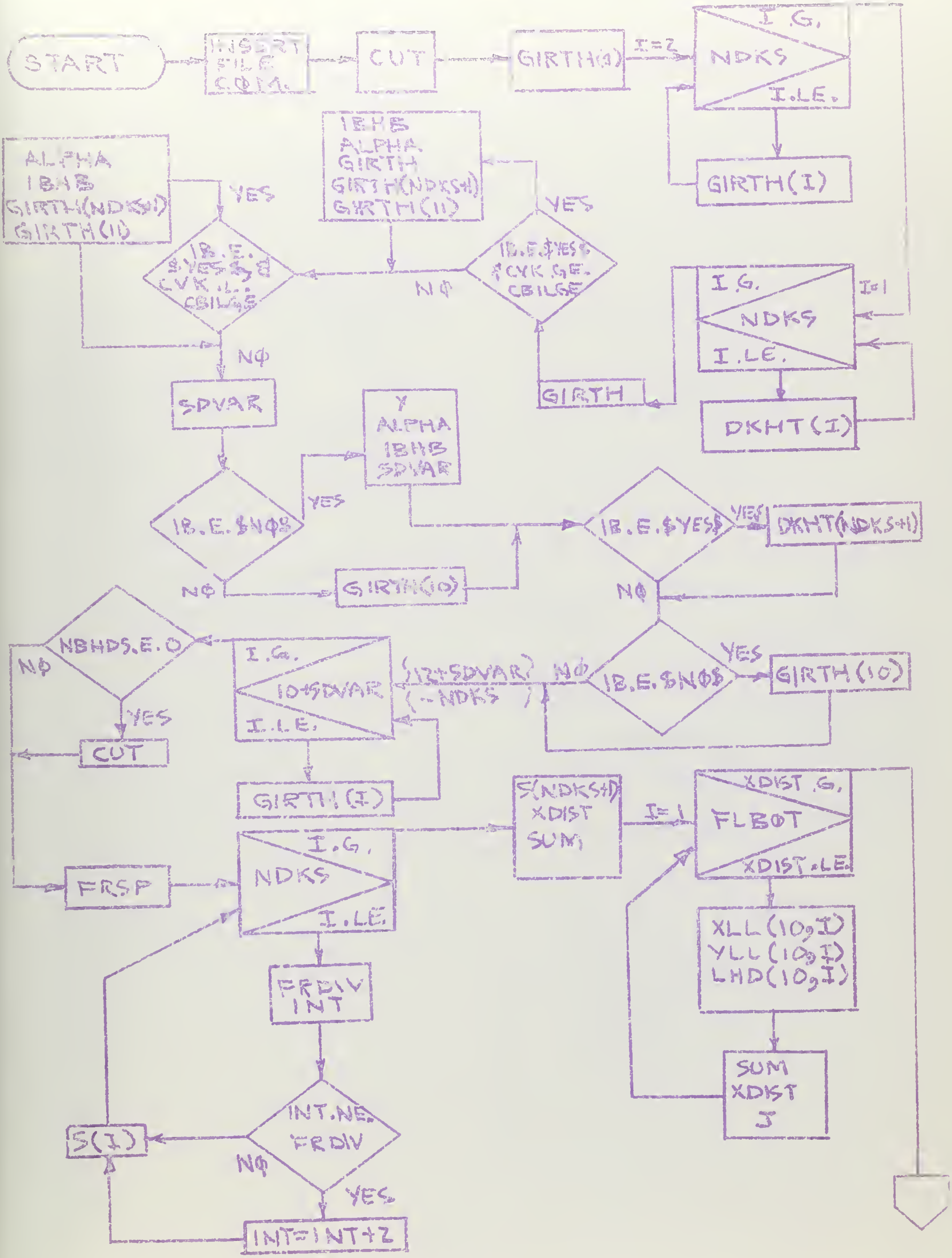
ALPHA	Angle measuring distance of inner bottom from center point of bilge turn.
BDIST	Incremented sum of frame spaces on the bulkheads.
BILGTH	Incremented sum of frame spaces on bulge turn.
CØUNT	The accumulative sum of longitudinals on shell side.
DELTA	Incremented angle between longitudinal upper bilge turn.
DKHT(I)	Array of the deck heights above the keel.
FRDIV	The first estimate of the number of longitudinals in a section.
GAMMA(I,J)	Angle of longitudinals on bilge turn up to inner bottom.
GIRTH(I)	Array of all the section lengths.
HMAX	Maximum water head chosen.
HMIN	Minimum water head possible.
IBHB	Inner bottom half breadth
INCLHD	Head on longitudinals when ship is inclined.
LCØUNT(I)	Array counting the longitudinals in each section.
LHD(I,J)	The water head on each longitudinal.
LL10	Accumulated sum of the longitudinals in Section 10.
LL11	Accumulated sum of the longitudinals in Section 11.
LLDK	Accumulated sum of the longitudinals on the decks.
LLIB	Accumulated sum of the longitudinals on the inner bottom.

SYMBOLS CALCULATED IN (STF.)

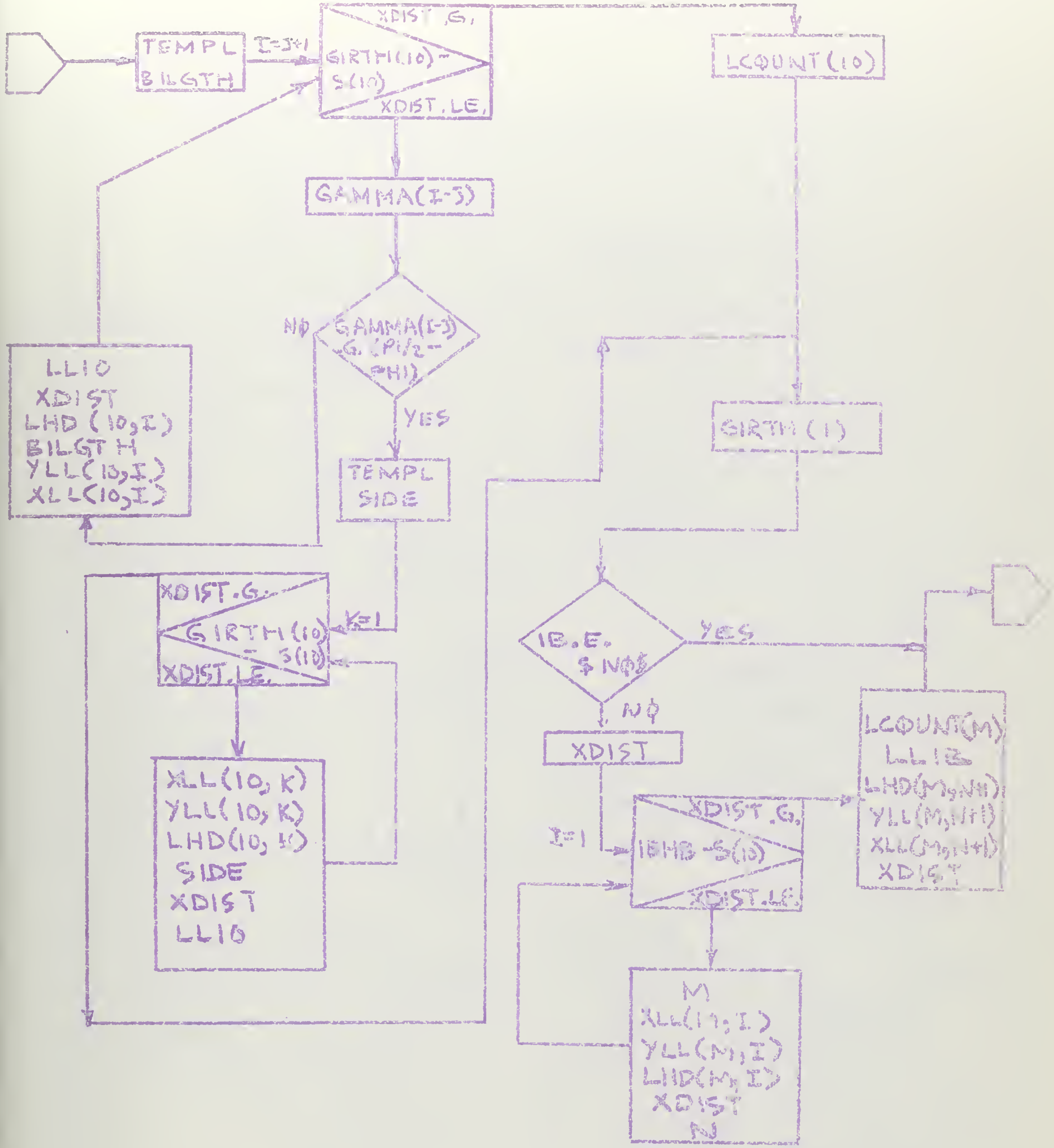
- 2 -

S(I)	Array of all the frame spacings in each section.
SDIST	The incremented frame spacing of each section on the shell side.
SDVAR	An integer which has the value NDKS when the ship has no inner bottom and the value NDKS+1 when an inner bottom exists.
SIDE	An incremented length at bilge bottom, similar to BILGTH.
SIDGTH	An incremented length in section 11 on the bilge turn.
SUM	A quanity describing several incremented totals used through out the program.
TDIST	Incremented frame spacing seen on the top deck.
TEMPL	The distance between the last longitudinal on the bottom shell and FLBOT.
TOTALL	The total number of longitudinals on the half section.
WHD	The wave head on the longitudinals.
XLL(I,J)	"X" coordinate of longitudinals.
YLL(I,J)	"Y" coordinate of longitudinals.

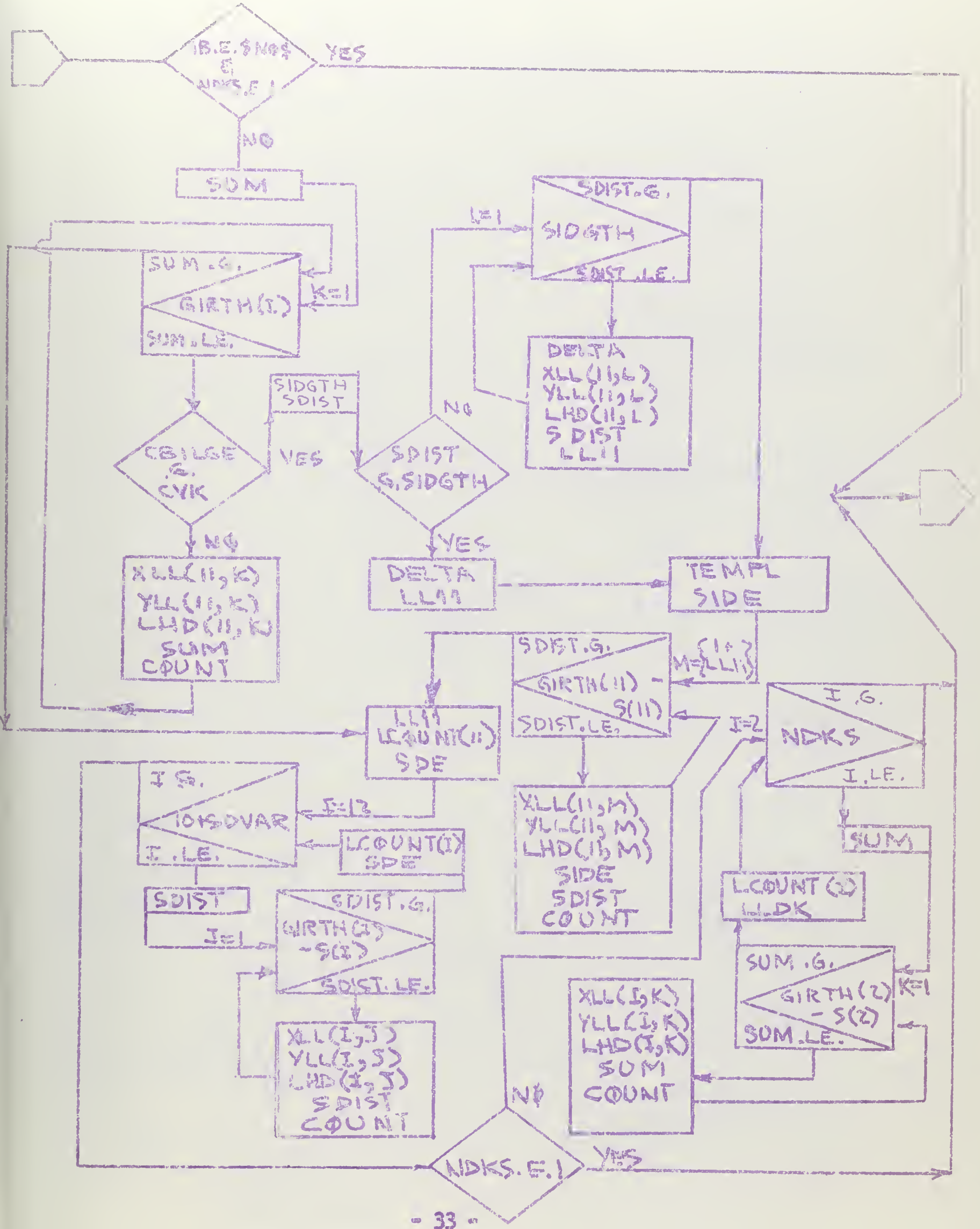
(CALCULATES STIFFENER GEOMETRY)

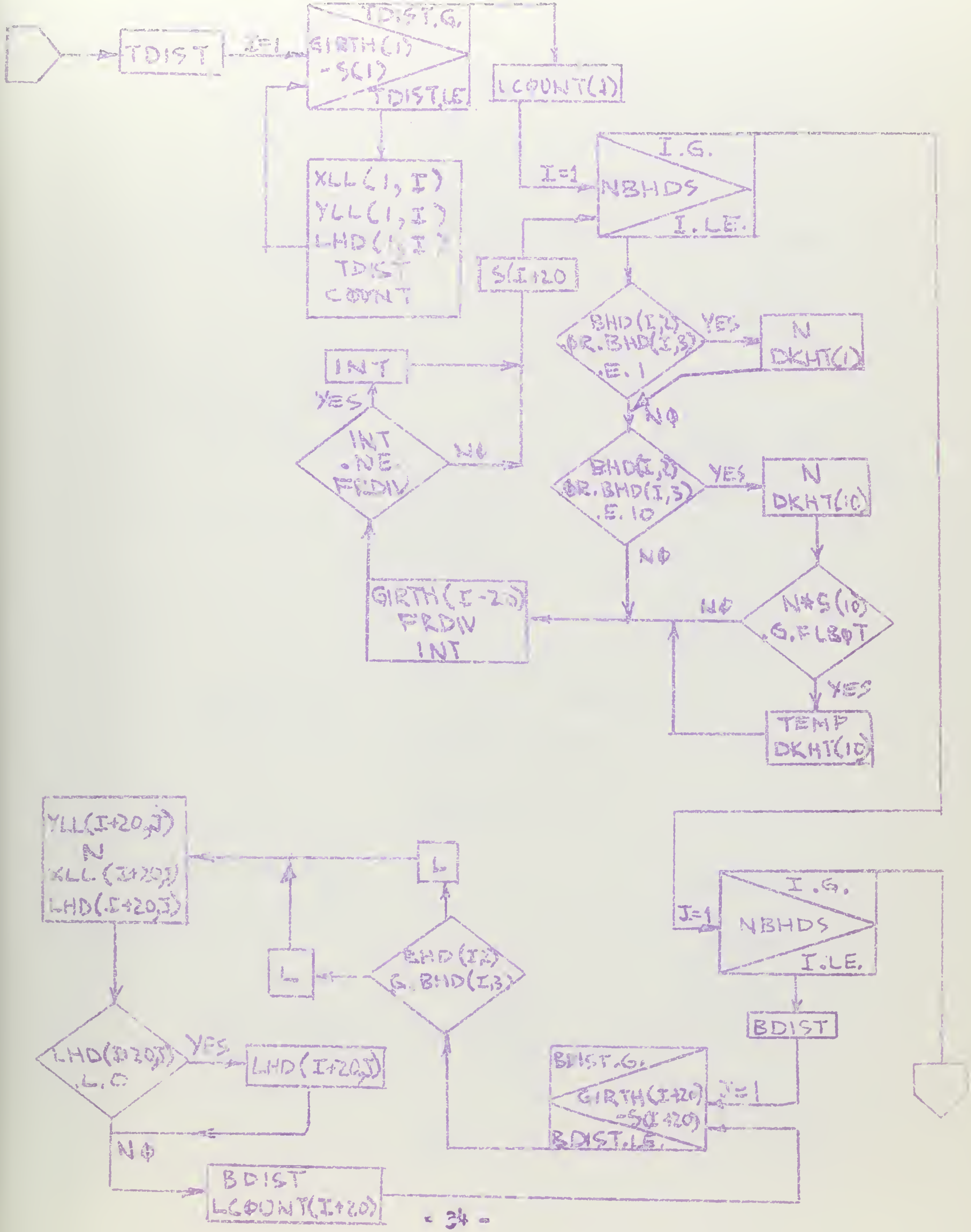


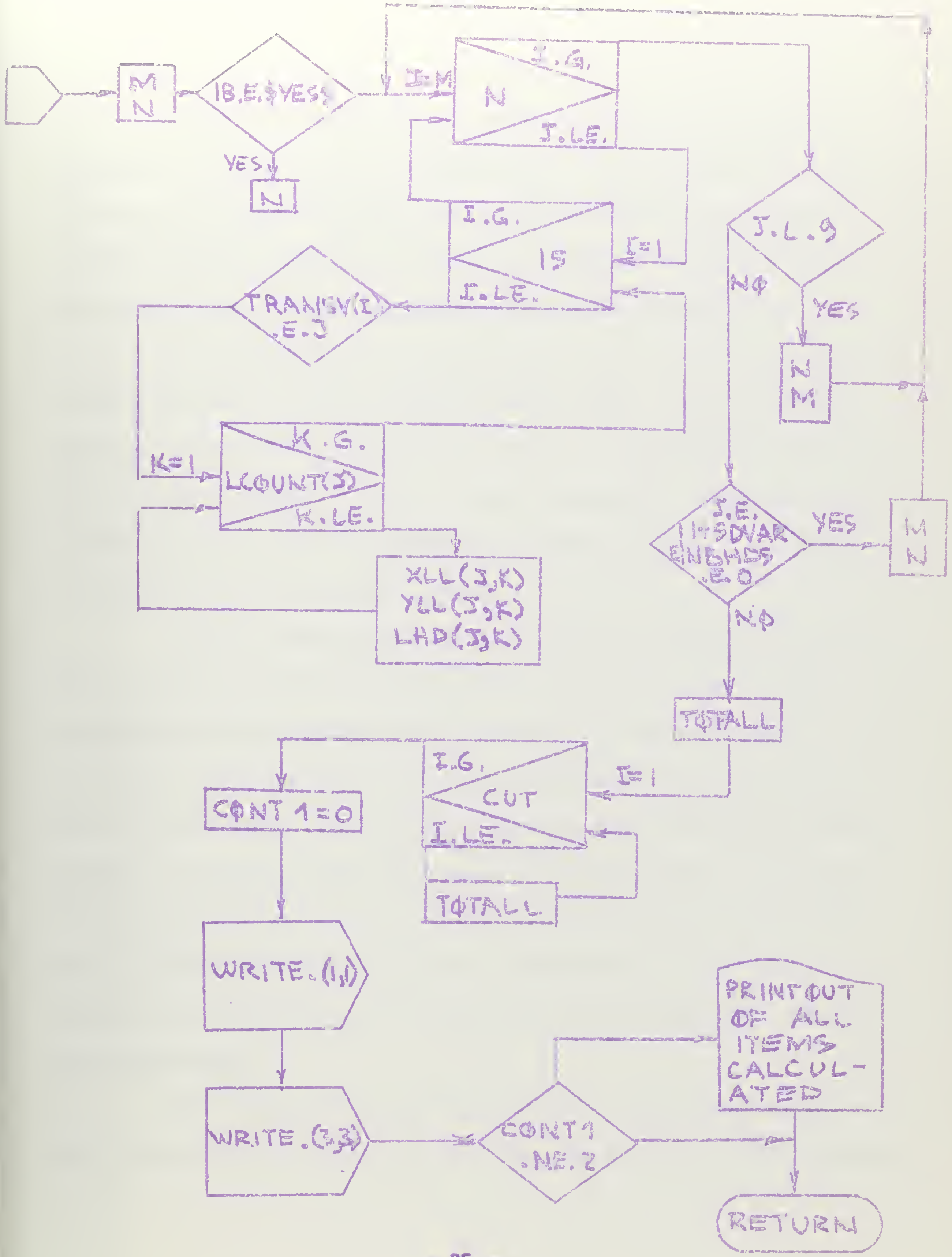
SIF (CONT)


TEMPL
BILGTH
I=I+1
XDIST .G.
GIRTH(10) - S(10)
XDIST .LE.
LCOUNT(10)
GAMMA(I-3)
NO
GAMMA(I-3) .G. (PI/2 - PHI)
YES
LL10
XDIST
LHD(10,I)
BILGTH
YLL(10,I)
XLL(10,I)
TEMPL
SIDE
GIRTH(I)
XDIST .G.
GIRTH(10) - S(10)
XDIST .LE.
K=1
XLL(10,K)
YLL(10,K)
LHD(10,K)
SIDE
XDIST
LL10
IB .E. NO
YES
NO
XDIST
I=1
XDIST .G.
IBHB - S(10)
XDIST .LE.
LCOUNT(M)
LL1B
LHD(M,N+1)
YLL(M,N+1)
XLL(M,N+1)
XDIST
M
XLL(M,I)
YLL(M,I)
LHD(M,I)
XDIST
N

STIF (CONT)


IB.E.NO
&
NDKS.E.1
YES
NO
SUM
SUM.G.
GIRTH(I)
SUM.LE.
K=1
SIDGTH
SDIST
CBILGE
.G.
CYK
YES
NO
XLL(II,K)
YLL(II,K)
LHD(II,K)
SUM
COUNT
L=1
SDIST.G.
SIDGTH
SDIST.LE.
DELTA
XLL(II,L)
YLL(II,L)
LHD(II,L)
SDIST
LL11
NO
SDIST
G.SIDGTH
YES
DELTA
LL11
TEMPL
SIDE
M={1+ LL11}
SDIST.G.
GIRTH(II) - S(II)
SDIST.LE.
LL11
LCOUNT(II)
SDE
I=2
I.G.
NDKS
I.LE.
I.G.
IOISOVAR
I.LE.
I=13
LCOUNT(I)
SDE
XLL(II,M)
YLL(II,M)
LHD(II,M)
SIDE
SDIST
COUNT
SUM
SDIST
J=1
SDIST.G.
GIRTH(I)
-S(I)
SDIST.LE.
LCOUNT(2)
LLDK
XLL(I,J)
YLL(I,J)
LHD(I,J)
SDIST
COUNT
SUM.G.
GIRTH(2)
- S(2)
SUM.LE.
K=1
XLL(I,K)
YLL(I,K)
LHD(I,K)
SUM
COUNT
NO
NDKS.E.1
YES


TDIST
I=1
TDIST.G.
GIRTH(I)
-S(I)
TDIST.LE.
LCOUNT(I)
XLL(1, I)
YLL(1, I)
LHD(1, I)
TDIST
COUNT
I=1
I.G.
NBHDS
I.LE.
S(I+20)
BHD(I,2)
.OR.BHD(I,3)
.E.1
YES
N
DKHT(1)
NO
INT
YES
INT
.NE.
FRDIV
NO
BHD(I,2)
.OR.BHD(I,3)
.E.10
YES
N
DKHT(10)
NO
GIRTH(I-20)
FRDIV
INT
NO
N*S(10)
.G.FLBOT
YES
TEMP
DKHT(10)
YLL(I+20,J)
N
XLL(I+20,J)
LHD(I+20,J)
L
L
BHD(I,2)
.G.BHD(I,3)
J=1
I.G.
NBHDS
I.LE.
BDIST
LHD(I+20,J)
.L.0
YES
LHD(I+20,J)
BDIST.G.
GIRTH(I+20)
-S(I+20)
BDIST.LE.
J=1
NO
BDIST
LCOUNT(I+20)


M
N
IB.E.YES
YES
N
I=M
I.G.
N
I.LE.
I.G.
15
I.LE.
I=1
J.L.9
NΦ
YES
N
M
TRANSV(I)
.E.J
K.G.
K=1
LCΦUNT(J)
K.LE.
XLL(J,K)
YLL(J,K)
LHD(J,K)
J.E.
1+SDVAR
EINBHDS
.E.0
YES
M
N
NΦ
TΦTALL
I.G.
I=1
CUT
I.LE.
TΦTALL
CΦNT 1=0
WRITE.(1,1)
PRINTΦUT
ΦF ALL
ITEMS
CALCUL-
ATED
WRITE.(3,3)
CONT1
.NE.2
RETURN

(PLT.)

"PLT" is a subroutine which determines all the geometric properties that depend upon the plate seams. When execution of this subroutine has been completed, the coordinate system for all longitudical continuous material in the midship section is fixed and the program is ready to begin the scantling selection procedure.

The first step in the execution of the "PLT" is the fixing of plate widths. The keel, center, margin, sheer, top, and stringer strake widths have been calculated in Ref. ( ) according to ABS rules. The relations obtained are used by this subroutine to preset the values of these plates. Next, a standard plate width based upon ship length is selected for all remaining plating.

When a standard size has been selected, the next step is to test all seam locations for interference with the stiffeners whose coordinates have been fixed. The keel plate is checked first and corrected if interference occurs, then the center strake is made to equal the keel width. The remaining standard plate widths must now be changed to a nominal size which yields an integer number of plates on the shell, the decks and on the bulkheads. Thus, every strake width has been determined. It remains now to check each one for interference with stiffeners and to store away all data needed by subsequent subroutines.

The shell seams are first examined. The distance along the shell from the center of the keel for each strake top is found; checked

against stiffener interference, and changed if necessary. Next the coordinates of the seams and the water head on them is calculated. The area, moment and inertia constants are also calculated for use later in the program.

Deck, inner bottom, and bulkhead plates are examined in a sequence similar to that of the shell. The distance of each seam from the deck side or bhd. bottom is found and checked against interference. Then the coordinates, water head, and area moment and inertia constants are found. Once these quantities are calculated, the program returns control to the main program. Before this is done, however, it is possible to obtain a print out of the data calculated in this subroutine. Refer to the chapter on program execution for the correct method.

List of Symbols Calculated in (PLT)

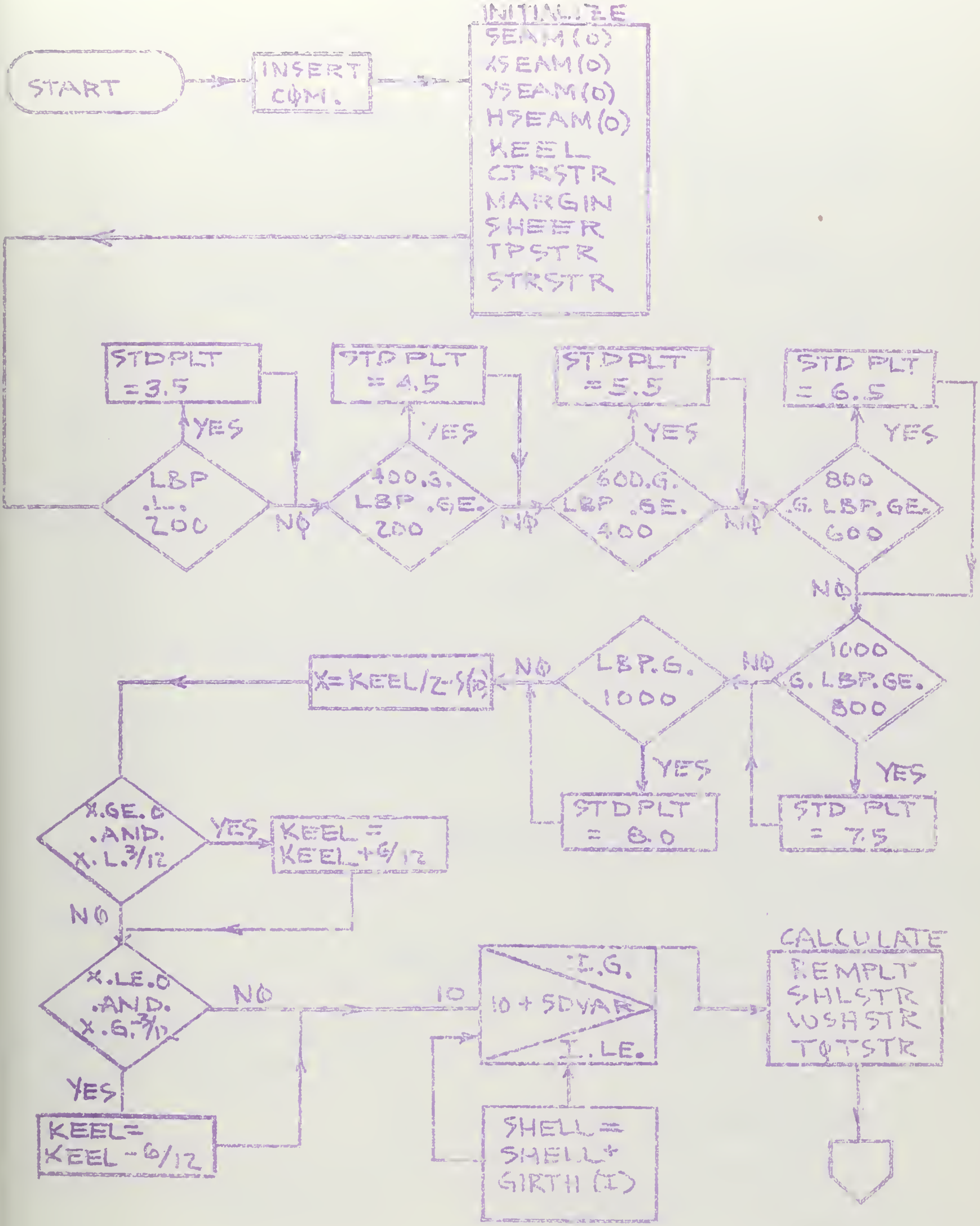
AC(J)	Area constant of "J"th plate dependent only on linear length of plate.
BDSTR(I)	Number of strakes on "I"th bhd.
CONT1	Key to print additional data
CTRSTR	Width of center strake on inner bottom
DKSTR(I)	Number of strakes on I"th deck.
ETA(J)	Angle between seam on bilge, similar to "GAMMA" in "STF",
ESEAM(J)	Water head on "J"th seam
IC(J)	Inertia constant of "J"th plate
keel	Keel plate width
Margin	Width of margin plate on inner bottom
MC(J)	Moment constant of "J"th plate
REMPLT	Length of all plating on shell except KEEL, SHEER, TPSTR.
SEAM(J)	The linear distance from the top seam of the "J" plate to the Keel.
SHEER	Width of sheer plate.
SHELL	Linear length of all plating on shell
SHLSTR	Number of plates on shell.
SPANST	The plate to be associated with each stiffener.
STDPLT	A nominal assumed standard width of plate to be dependent on ship length.
STRSTR	Stringer plate
SUM1	Accumulated sum of GURTH(I) up the side from the keel.
TODK	Number of plates on all the decks
TOTSTR	Accumulated sum of all the plates on the half section.

List of Symbols Calculated in (Cont)

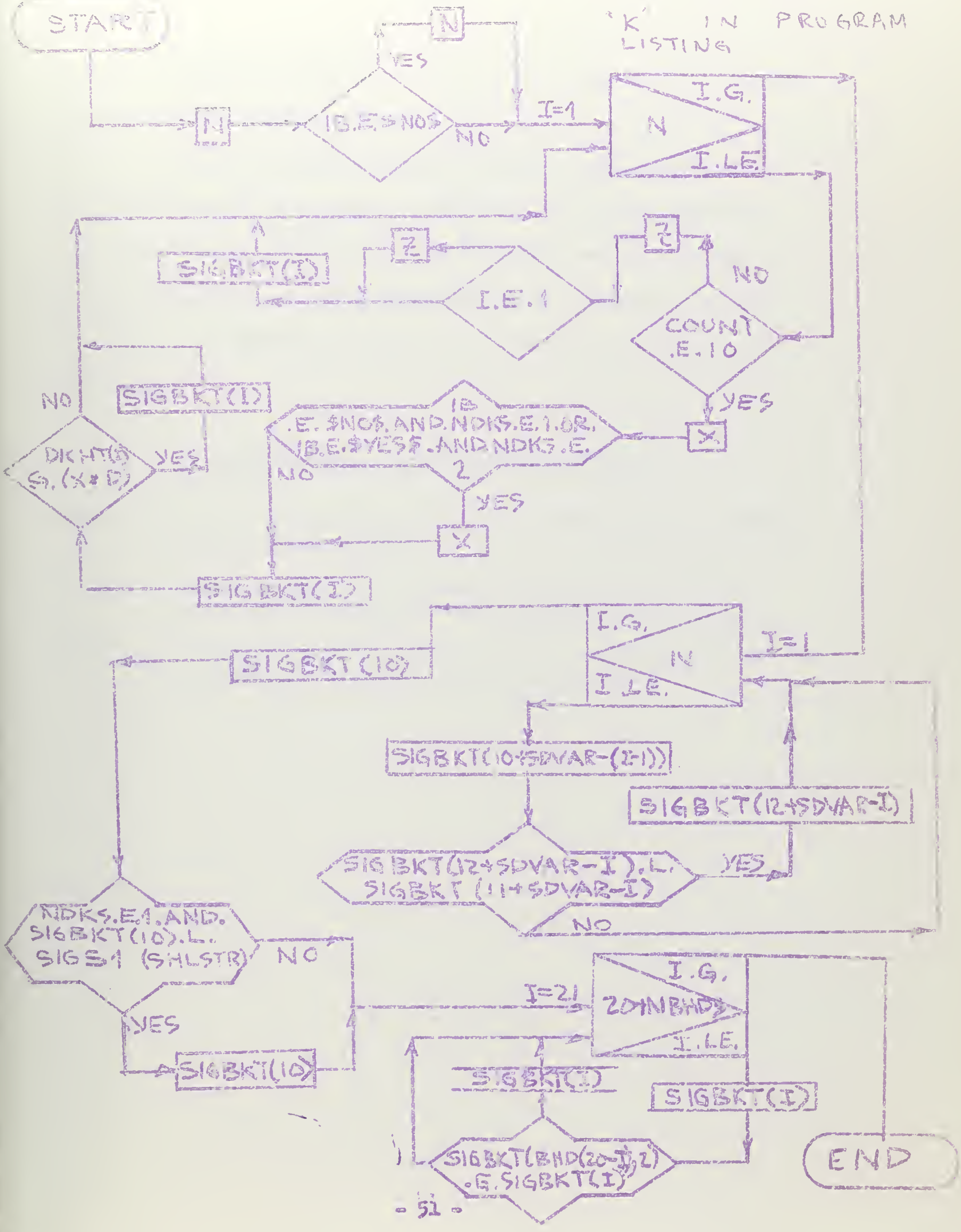
- 2 -

TPSTR	Top strake
WBDSTR(I)	Nominal width of each plate on "I"th bhd.
WOKSTR(I)	Nominal width of each plate on the "I"th deck.
WSHLST	Nominal width of each plate on shell
X SEAM (J)	"X" coordinate of "J"th seam
Y SEAM (J)	"Y" coordinate of "J"th seam

(CALCULATES SHELL GEOMETRY)



* NOTE:
ALL 'I' ARE
'K' IN PROGRAM
LISTING



AMISTF.

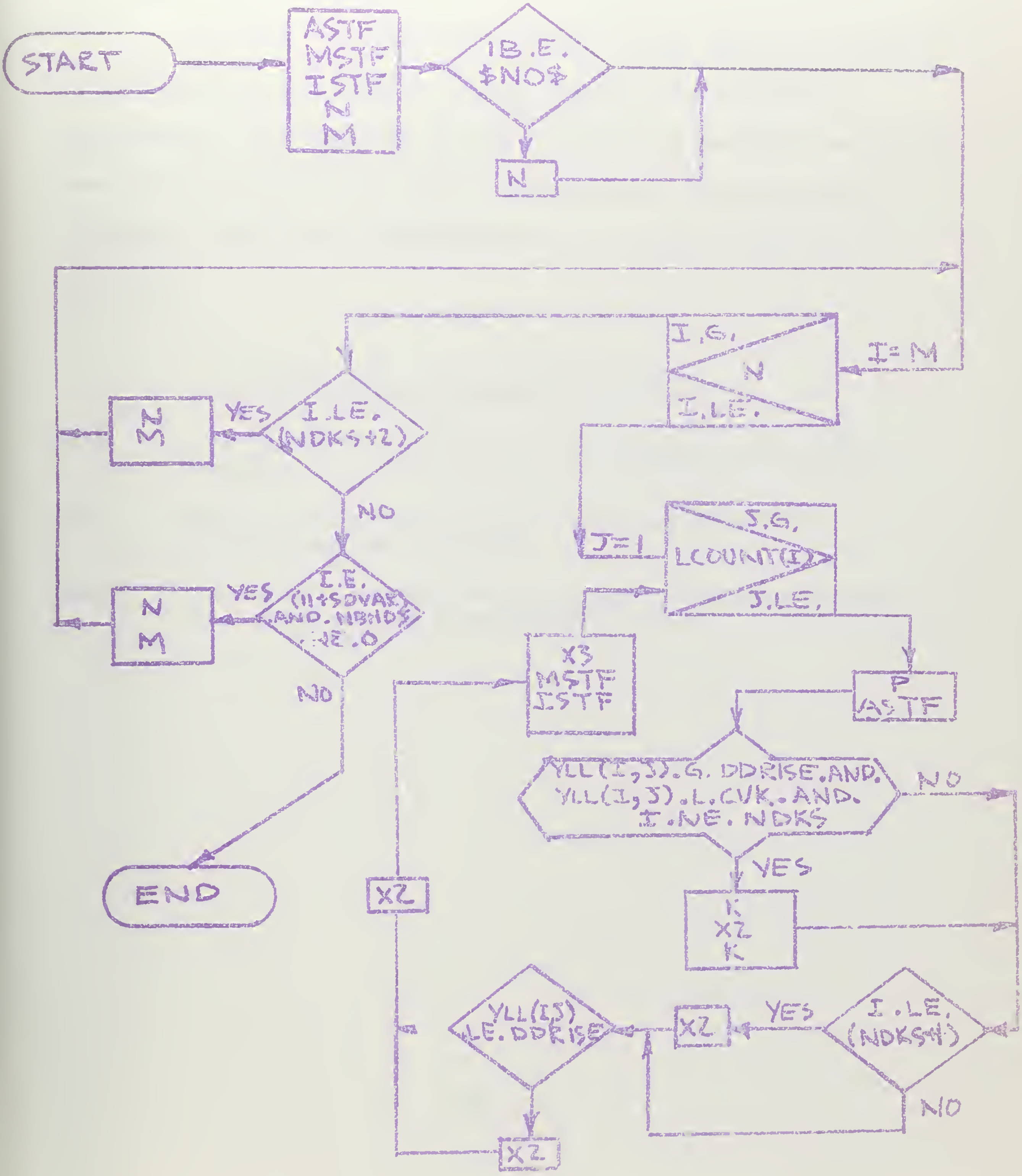
(AMISTF.) calculates the total area, moment and inertia of the stiffeners about the base line.

Using the value of proportionality constant for each stiffener location determined in (STFNER.), the area, moment and inertia of each stiffener is calculated. The resulting values for each stiffener can be added, since they were taken about the same base line, thus giving the total area, moment and inertia of all the stiffeners.

LIST OF SYMBOLS CALCULATED IN (AMISTF.)

ASTF	Total cross-sectional area of the longitudinal stiffeners at the midship section.
ISTF	Moment of inertia of the cross-sectional area of the longitudinal stiffeners about the base line.
MSTF	Internal bending moment of the cross-sectional area of the longitudinal stiffeners about the base line.

AMISTF.


START
ASTF
MSTF
ISTF
N
M
IB.E.
NO
N
I=M
I.G.
N
I.LE.
I.LE.
(NDKS+2)
YES
N
M
NO
I.E.
(11+SDVAR)
.AND. NB:NDS
.NE.0
YES
N
M
NO
END
J=1
J.G.
LCOUNT(I)
J.LE.
X3
MSTF
ISTF
P
ASTF
YLL(I,J).G. DDRISE.AND.
YLL(I,J).L.CVK..AND.
I.NE.NDKS
NO
YES
K
XZ
K
XZ
I.LE.
(NDKS+1)
YES
NO
XZ
YLL(I,J)
.LE.DDRISE
XZ

AMIPLT.

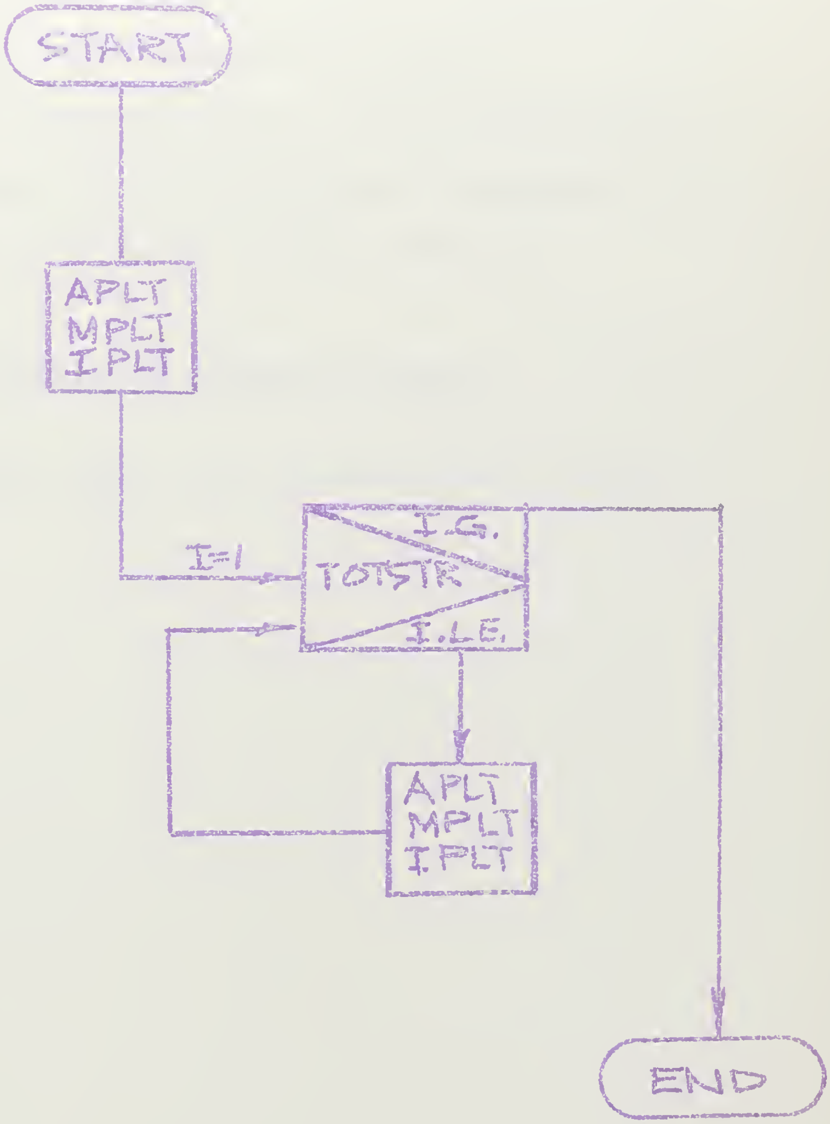
(AMIPLT.) calculates the total area, moment and inertia of the plates about the base line.

Using the values of area constant, moment constant and inertia constant calculated in (PLT.), and the current value of plating thicknesses in the sub-cycle, the area, moment and inertia of each plate about the base line is calculated. The resulting values are added, giving the total area, moment and inertia of all plates about the base line.

LIST OF SYMBOLS CALCULATED IN (AMIPLT.)

APLT	Total cross-sectional area of the plating at the midship section.
IPLT	Moment of inertia of the cross-sectional area of the plating about the base line.
MPLT	Internal or resisting bending moment of the cross-sectional area of the plating about the base line.

AMIPLT.



INTERP

(INTERP.) is an internal function which interpolates the Section Modulus versus Proportionality Constant curve generated in the subroutine (STIFF.) for each stiffener location.

By LaGrangian interpolation, the subroutine selects the proportionality constant of the basic stiffener corresponding to a required section modulus of a plate-stiffener combination.

LIST OF SYMBOLS CALCULATED IN (INTERP.)

TEMP	Dummy variable equal to the proportionality constant.

STFNER.

For longitudinally framed sections, (STFNER.) calculates the size of longitudinal stiffener required for each plate-stiffener combination to withstand the maximum stresses.

Whenever (STFNER.) is executed by (CYC.), the coordinates of the stiffeners, water heads, plate thicknesses associated with each stiffener location, and the stresses for the current sub-cycle are known. It is the purpose of this subroutine to determine the required stiffener scantlings.

A scale factor or proportionality constant, PROPCO, based on the geometry of the basic stiffener and an effective plate width of 60 x thickness or the longitudinal frame spacing, whichever is less, is used to determine the geometric properties of the required stiffener.

For each stiffener location and its associated plate thickness, (STFNER.) calculates fifteen values of section modulus for each plate-stiffener combination, by using fifteen different values of PROPCO. In effect, a curve of section modulus versus proportionality constant is generated for each stiffener location. The actual section modulus required to resist the stresses in the current sub-cycle is a point on the curve. To design a ship that approximately meets the American Bureau of Shipping Rules, a section modulus required by the Rules, MODABS, is initially selected as the minimum required section modulus of the plate-stiffener combination. With this initial value of MODABS, the subroutine (INTERP.) interpolates the section modulus versus proportionality constant curve to determine the PROPCO associated with the initially selected value of MODABS. With this value of PROPCO, (STFNER.) calculates the properties of the stiffener-plate combination for that stiffener location.

To determine if this combination will fail due to instability, under the combined primary and secondary stresses, Timoshenko's Formula for combined lateral and axial loadings on a beam is used. The section modulus, ZT1M, from Timoshenko's Formula is a function of the geometric properties of the plate-stiffener combination and the applied loads. Thus, corresponding to the initial value of MODABS and PROPCO, a value of section modulus, ZT1M, is calculated by Timoshenko's Formula. Three possible situations exist at this point:

I. ZT1M equals MODABS

II. ZT1M less than MODABS

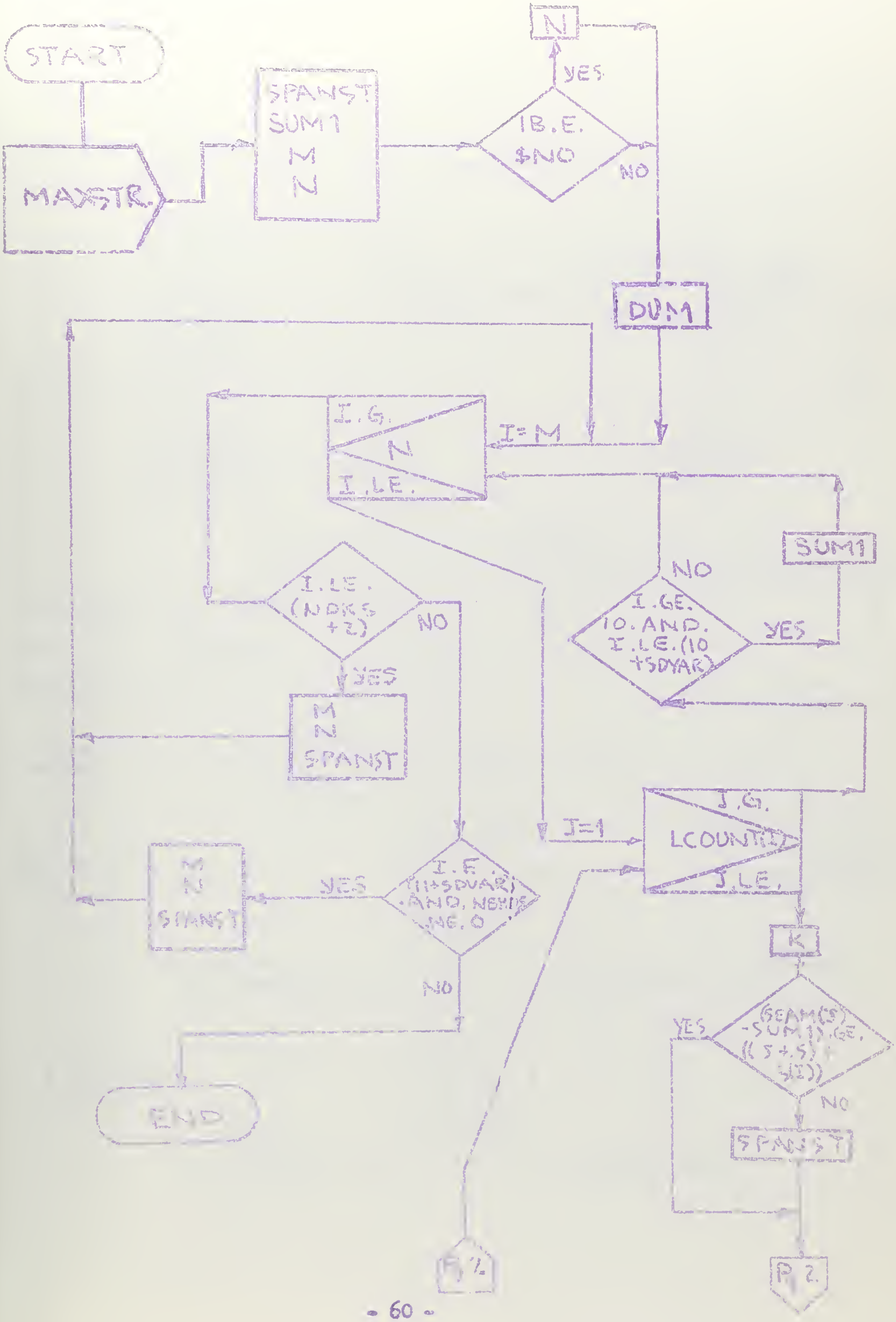
III. ZT1M greater than MODABS

In case I, when ZT1M and MODABS differ by not more than 0.75, MODABS is considered to equal ZT1M, and is the required section modulus for the plate-stiffener combination.

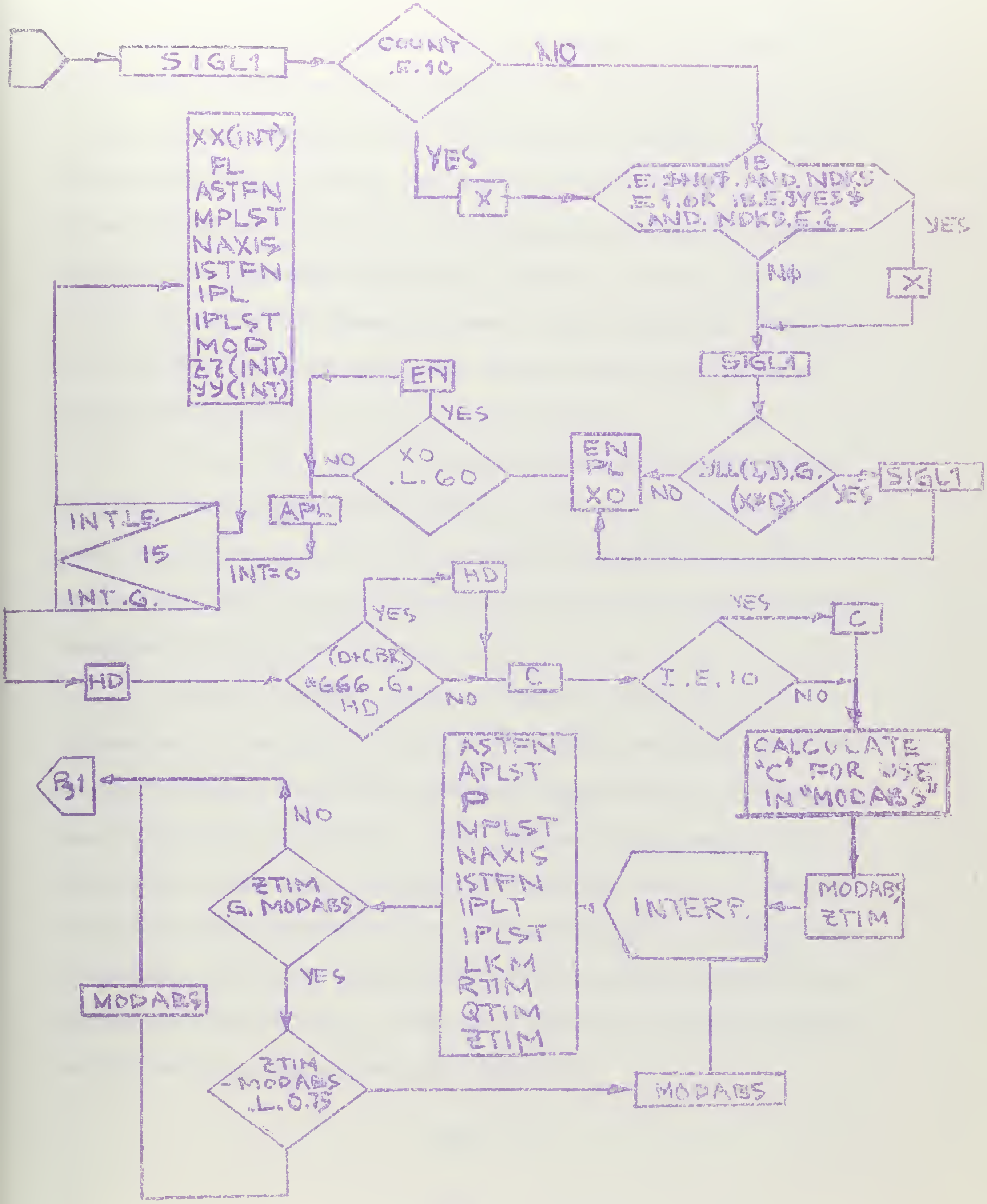
In case II, since ZT1M is less than the ABS value, MODABS governs and the value of PROPCO associated with MODABS is the required one.

In Case III, when ZT1M is greater than MODABS, ZT1M must be the governing section modulus. But the value of PROPCO was determined from the initial value of MODABS and does not correspond to ZT1M. A new value of MODABS is chosen such that the value of PROPCO determined by this new value of MODABS also corresponds to the value of ZT1M. To converge on a solution, the mean value between ZT1M and MODABS is selected as the new initial value of MODABS. A greater value of PROPCO results, and the two section moduli, ZT1M and MODABS based on this new

these are again computed. This cycling process terminates when both [illegible] and [illegible] are the same, only then will the program produce stiffener scantlings that satisfy both [illegible] and [illegible]. The above procedure is repeated for each stiffener location.


START
MAXSTR.
SPANST
SUM1
M
N
IB.E.
$NO
YES
N
NO
DUM
I.G.
N
I.LE.
I=M
NO
I.GE.
10.AND.
I.LE.(10
+SDVAR)
YES
SUM1
I.LE.
(NDKS
+2)
NO
YES
M
N
SPANST
J=1
J.G.
LCOUNT(I)
J.LE.
M
N
SPANST
YES
I.E.
(1+SDVAR)
.AND. NSHDS
.NE. 0
NO
K
(SEAM(S)
-SUM1).GE.
((5+.5)*
SI))
YES
NO
SPANST
END
P2
P2

STFNER. (CONT.)


SIGL1
COUNT .G.10
NO
YES
X
XX(INT)
FL
ASTFN
MPLST
NAXIS
ISTFN
IPL
IPLST
MOD
ZZ(INT)
YY(INT)
IB .E. NO .AND. NDKS .E.1.OR IB.E.YES .AND. NDKS.E.2
YES
NO
X
SIGL1
EN
YES
NO
XO .L. 60
EN
FL
XO
NO
YLL(I,J).G. (X*D)
YES
SIGL1
INT.LE.
15
INT.G.
APL
INT=0
HD
YES
HD
(D+CBR) *666 .G. HD
NO
C
YES
C
I .E. 10
NO
CALCULATE "C" FOR USE IN "MODABS"
P31
NO
ZTIM .G. MODABS
YES
MODABS
ASTFN
APLST
P
MPLST
NAXIS
ISTFN
IPLT
IPLST
LKM
RTIM
QTIM
ZTIM
INTERP.
MODABS
ZTIM
ZTIM -MODABS .L. 0.75
MODABS

[illegible]

This subroutine is called by (CYC.) in order to refine the thicknesses of plating required to withstand the static water head. Each plate has two possible geometric arrangements. The geometry of the transversely framed and longitudinally framed sections each require a separate stress distribution. The subroutine (MAXSTF.) is called to calculate the maximum stress associated with each section; this will be the stress upon the plates in the transversely framed sections. Otherwise, the stresses calculated in (STRES1.) are used as a basis for the longitudinally framed sections. Those stresses in (STRES1.) are associated with each seam. The stress on each plate is determined from the maximum of the two seam stresses.

The array CO_i is next filled with the plating thicknesses based upon formulae that approximate ABS rule requirements (Ref. No.), using the stresses described above. These thicknesses are those necessary to meet the stress schedule set up in the current sub-cycle being run in subroutine (CYC.).

Several different values are used to calculate the thicknesses of each plate. Since the program is currently set to meet merchant criteria, some plate scantlings depend upon the location, and upon the ABS rule requirements. The formulas for the center plate, keel plate, sheerstrake, stringer plate, and top strake are presently all special cases designed to meet ABS requirements. A re-orientation of the long side in the longitudinally framed section requires a new formula for calculating CO_i. This is triggered by the program when a section having no longitudinals is encountered.

[illegible] function is calculated to average the new thicknesses with the old thicknesses calculated in the last sub-cycle in subroutine (CYC.).

$$T_{i2} = (CO_i + WT \times T_{i1}) / (WT + 1) \qquad (1)$$

T_{i2} = New thickness of ith plate.

T_{i1} = Old thickness of ith plate.

CO_i = Thickness of ith plate just calculated based upon local lateral load.

WT = Weighting function associated with ith plate.

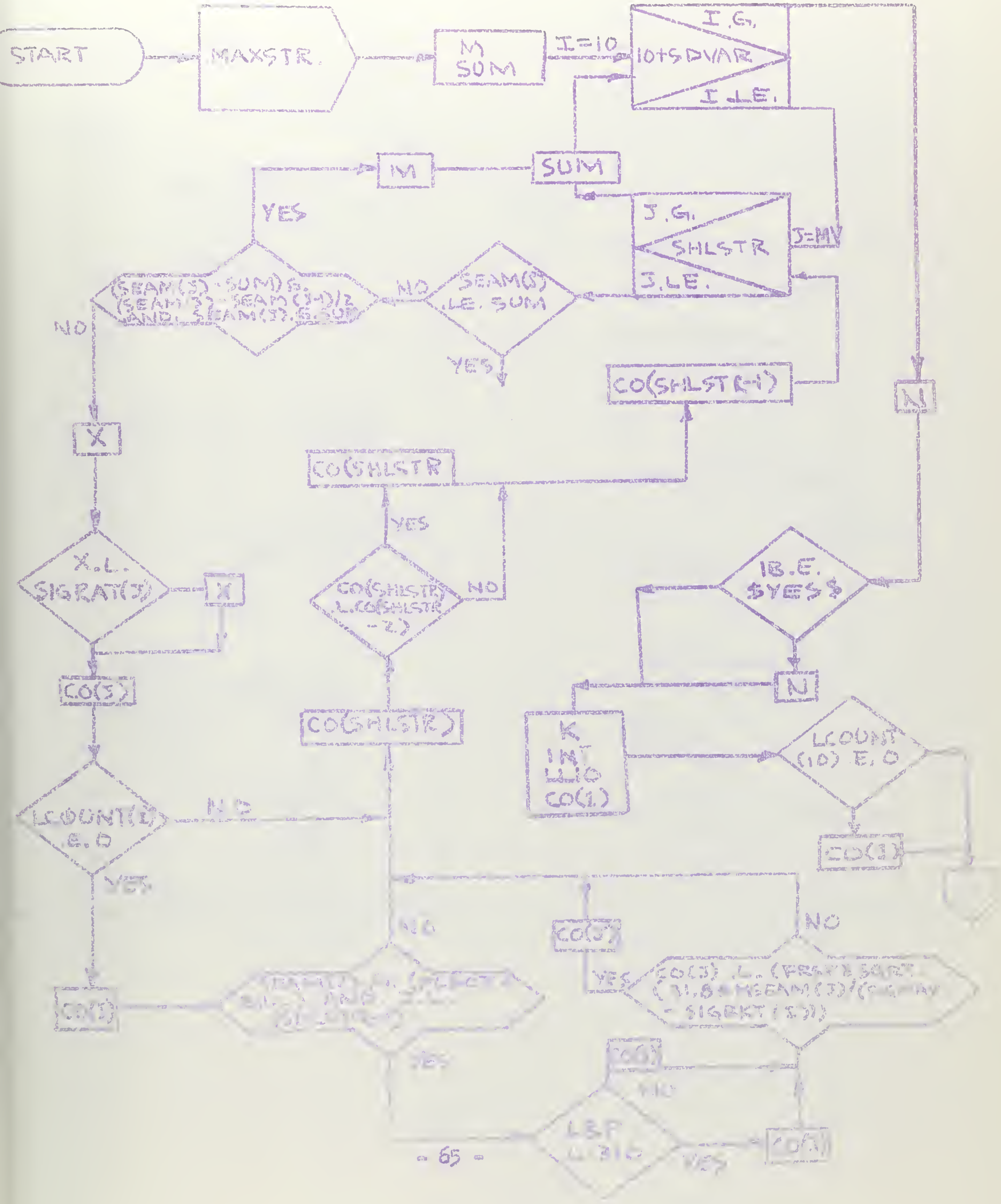
The weighting function is used to prevent the change in thickness during each sub-cycle from becoming too rapid, thus upsetting the cycling procedure.

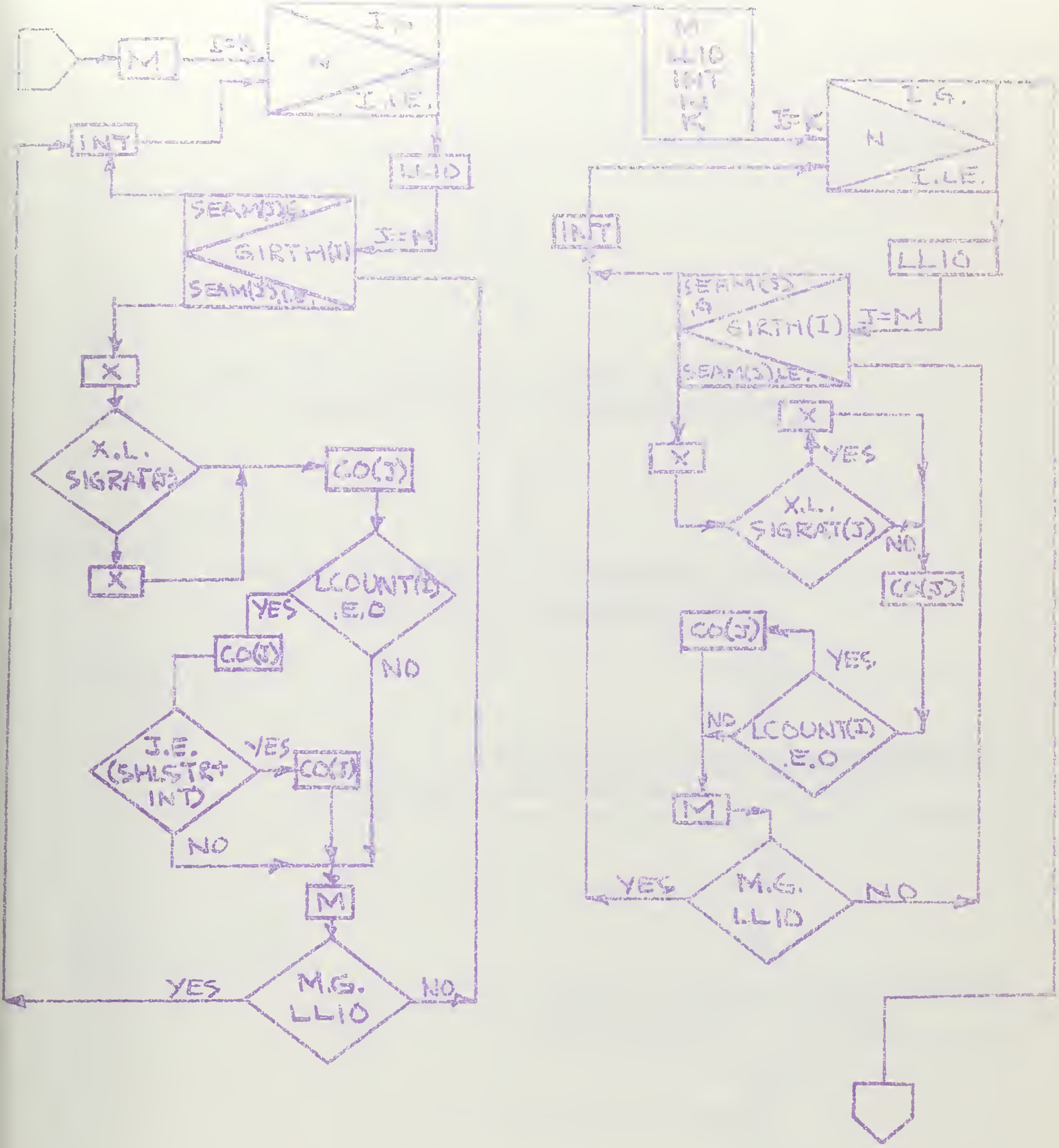
The iteration for each plate in each sub-cycle, once the CO_i array is completed, consists of three steps. First, a correct weighting function is determined. This function is designed to permit the most rapid change of plate thicknesses in each sub-cycle to occur on plates which will not be changed by the linear extrapolation program. These are the plates furthest from the fibers which are found to have plates whose primary stress is above the limiting steps. The second step is to fill the second column (T_{i2}) of that six column array described in (CYC.). This is done in accordance with formula (1). At the first calling of this subroutine by (CYC.) the initial thicknesses are calculated. This is signified by setting the value of COUNT equal to 10. For this case there is no set of thicknesses in column one of the array to be averaged, so column two is set directly equal to the thicknesses based upon local lateral load. The last step is the replacement of column one by the new thicknesses in column two. These are now the new initial thicknesses to be used in the next sub-cycle. Control is returned to (CYC.).

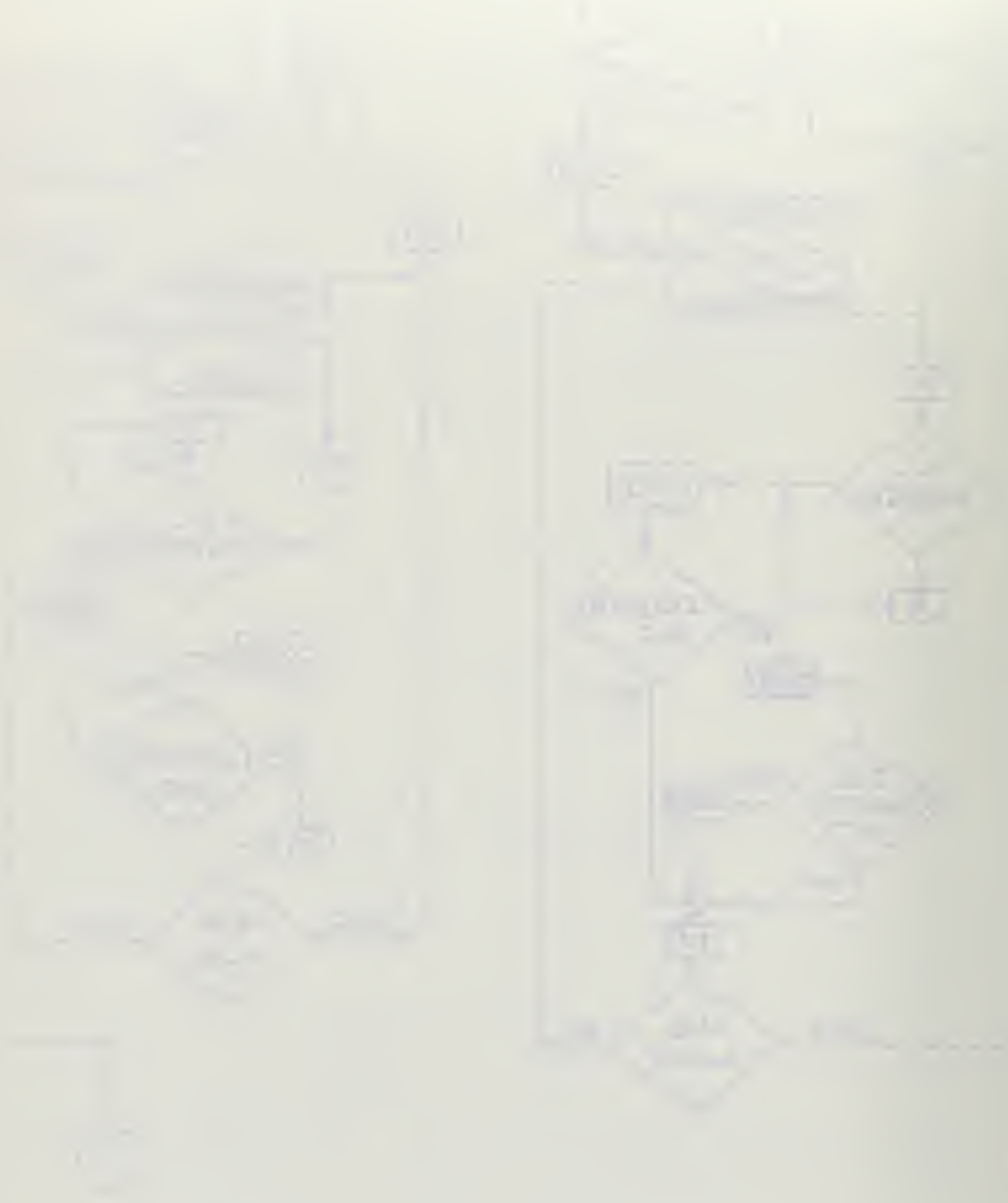
LIST OF SYMBOLS CALCULATED IN (THKNES.)

CO(J)	The plate thickness based upon lateral load.
T(I, CYCLE)	The thickness used for each subcycle of (CYC).
T(I, CYCLE + 1)	The thickness found from the weighted average of T (I, CYCLE) and CO(J).
WT	The weighting function for each plate.
X	The maximum seam stress associated with each plate.

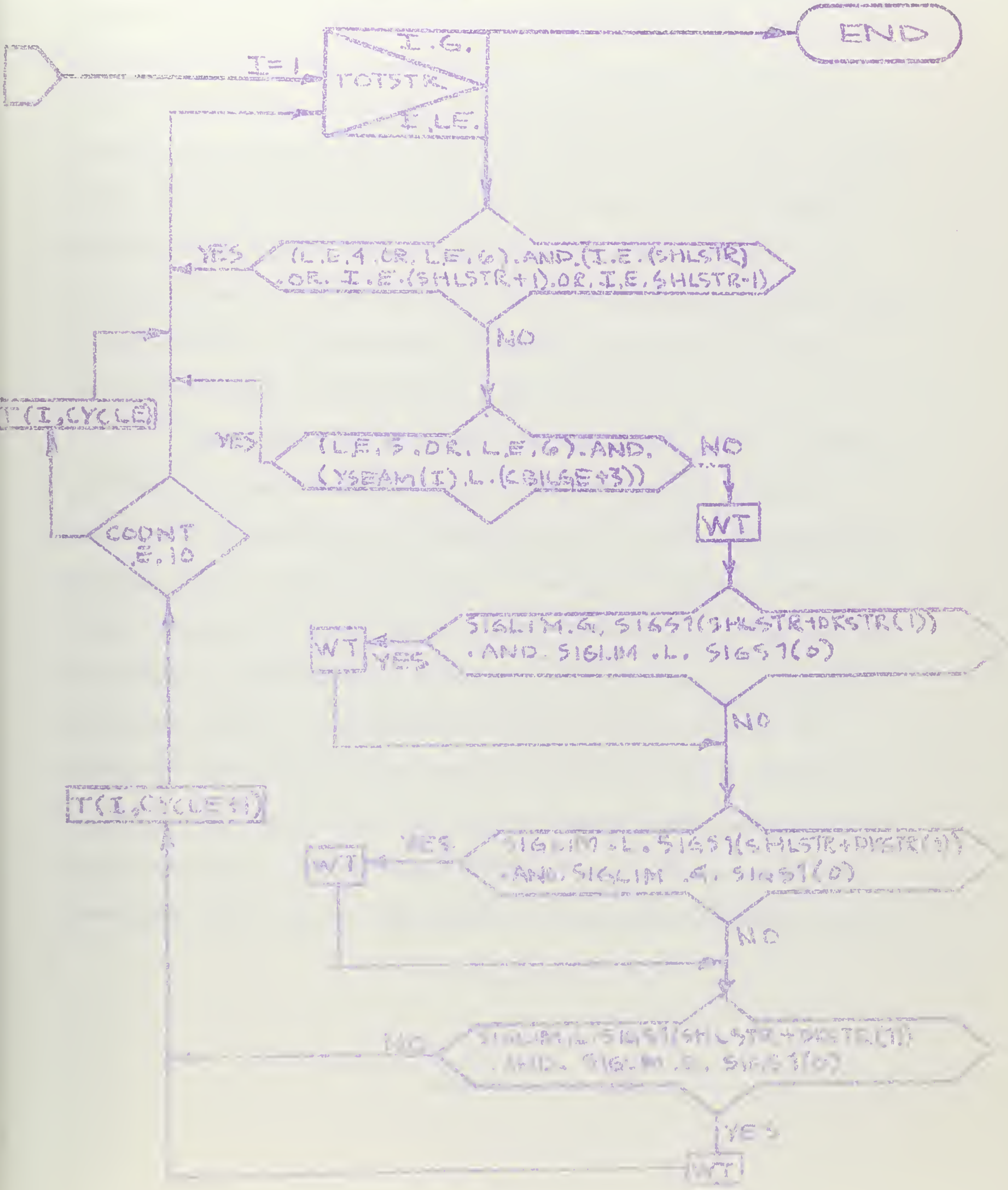
THKNES.


START
MAXSTR.
M
SUM
I=10
I.G.
10+SDVAR
I.LE.
M
SUM
YES
J.G.
SHLSTR
J.LE.
J=MV
(SEAM(J).SUM).G.
(SEAM(J)+SEAM(J-1))/2
.AND. SEAM(J).G.SUM
NO
SEAM(J)
.LE. SUM
YES
NO
CO(SHLSTR-1)
N
X
CO(SHLSTR
YES
X.L.
SIGRAT(J)
X
CO(SHLSTR)
.L.CO(SHLSTR
-2)
NO
IB.E.
YES
CO(J)
N
CO(SHLSTR)
K
INT
LL10
CO(1)
LCOUNT
(10) E.O
LCOUNT(I)
.E.O
NO
YES
CO(1)
NO
CO(J)
NO
YES
CO(J)
CO(J) .L. (FRAY*SQRT
(1.8*HSEAM(J)/(SIGMAY
- SIGBKT(I)))
CO(I)
YES
CO(J)
NO
LBP
.L.316
YES
CO(J)


2
M
J=K
I=
N
I.L.E.
INT
LLIO
SEAM(J).G.
GIRTH(I)
J=M
SEAM(J).L.E.
X
X.L.
SIGRAT(J)
CO(J)
X
LCOUNT(I)
.E.O
YES
CO(I)
NO
J.E.
(SHLSTR+
INT)
YES
CO(J)
NO
M
M.G.
LLIO
YES
NO
M
LLIO
INT
N
K
J=K
I.G.
N
I.L.E.
INT
LLIO
SEAM(J)
.G.
GIRTH(I)
J=M
SEAM(J).LE.
X
X
YES
X.L.
SIGRAT(J)
NO
CO(J)
CO(J)
YES
NO
LCOUNT(I)
.E.O
M
M.G.
LLIO
YES
NO



THKNES. (CONT)


END
I=1
I.G.
TOTSTR
I.LE.
YES
(L.E.4.OR.L.E.6).AND.(I.E.(SHLSTR)
.OR. I.E.(SHLSTR+1).OR.I.E.SHLSTR-1)
NO
T(I,CYCLE)
YES
(L.E.5.OR.L.E.6).AND.
(YSEAM(I).L.(SBILGE+3))
NO
WT
COONT
.E.10
WT
YES
SIGLIM.G. SIGS1(SHLSTR+DKSTR(1))
.AND. SIGLIM .L. SIGS1(0)
NO
T(I,CYCLE+1)
WT
YES
SIGLIM.L.SIGS1(SHLSTR+DKSTR(1))
.AND. SIGLIM .G. SIGS1(0)
NO
NO
SIGLIM.L.SIGS1(SHLSTR+DKSTR(1))
.AND. SIGLIM.G. SIGS1(0)
YES
WT

Subroutine (CYC.) is the controlling subroutine. All geometric properties have been calculated in subroutines (PLT.) and (STF.). The program must now design the best hull possible given the coordinate system found in (PLT.) and (STF.). Beginning with a set of initial thicknesses, arbitrarily based upon the geometry and upon the limiting stress; the scantlings are cycled from the initial set to a final set which meets all stress criteria in a logical design sequence. This cycling procedure is rather involved, so to understand the design method in its entirety, an understanding of each sub-cycle and its place in the overall scheme of the main cycle is mandatory.

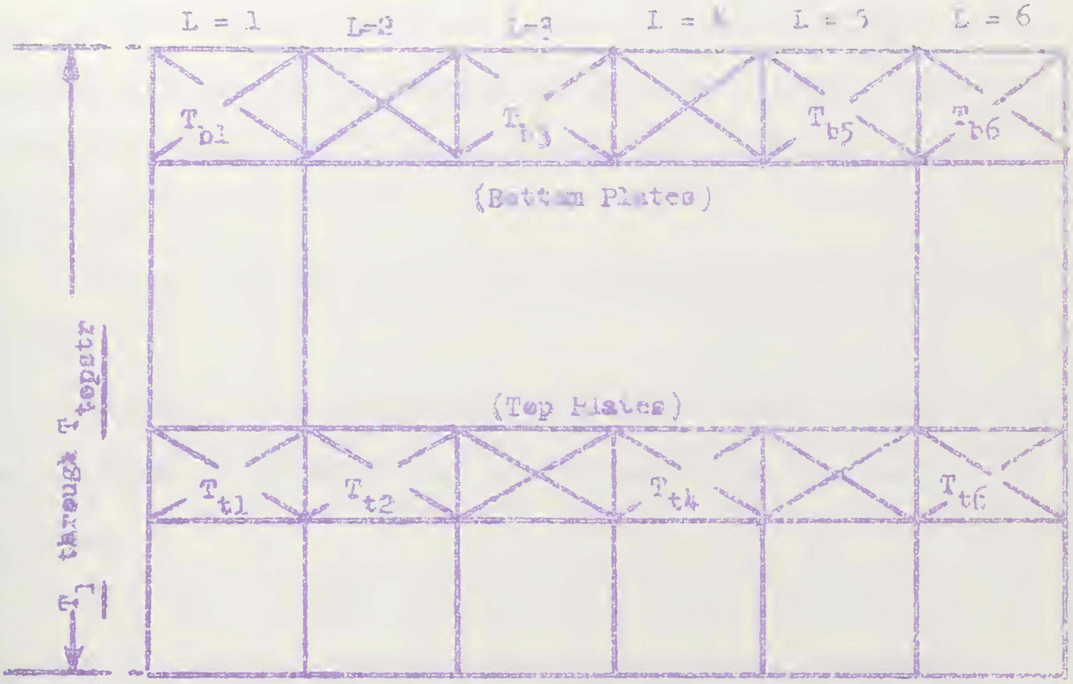
The ultimate aim of each main cycle in (CYC.) is to satisfy the limiting primary bending stress on the hull girder. Cycle #1 begins with the selection of an arbitrary set of initial thicknesses as mentioned above. This job is done by subroutine (THKNES.) based on a stress schedule set up by (STRES1.). The stiffener scantlings are now determined by (STFNER.) based upon those stresses found in (STRES2.). Subroutine (AMIPLT.) and (AMISTR) determine the area, moment, and inertia of this initial set of scantlings and now Cycle #1 moves to a sub-cycle which designs the scantlings to resist lateral stress due to static water head. (STRES1.) and (STRES2.) set up a stress schedule based upon areas, moments, and inertias of previously calculated members.

using these stresses. ([illegible]) refines the current plate thicknesses to resist lateral stress, and ([illegible]) calculates the associated stiffener scantlings. The sub-cycling continues until a suitable refinement is accomplished.

The next step is to attempt to satisfy the primary bending stress using the thicknesses found by the static head requirement. This will be called Cycle A, and refers to the part of the cycle which increases the thicknesses of plates that lie on the outer fiber. Cycle B will refer to the cycle which attempts to satisfy the primary bending stress by increasing plates which would buckle under the current stress schedule. A trigger is set that tells (CYC.) which cycle is being executed. Whenever the quanity METER is set equal to 1, Cycle A is being executed, but when METER equals 0, the subroutine is performing Cycle B. Cycles A and B both make use of a linear program to increase the area of the midship cross section to reduce primary bending.

The array T_{ij} is shown in Fig. as having six columns, and a number of rows equal to the number of plates on the cross-section. The first column is the thicknesses of plating needed to resist lateral load. The remaining five columns are set equal to the first, in order that the linear program may operate upon the array to chante the thicknesses for an optimum stress decrement.

The Array T_{IJ}



T_{b1} = Plates below neutral axis increased by linear extrapolation.

T_{t1} = Plates above neutral axis increased by linear extrapolation.

L = Column index

FIG. 2

[illegible]

[illegible]

[illegible]

[illegible]

The first step in the linear program is to make an incremented increase to the thicknesses of the bottom plating in column 2 and to the top plating in column 3. The linear program calculates the unit effect of these increments and displays the results in columns 4 through 6. Column 4 is the set of new top thicknesses causing a stress decrease in the top. Column 5 is the new bottom thicknesses causing a stress decrease in the bottom fibers. Column 6 has new top and bottom thicknesses for a decrease in stress at both the bottom and top.

Column 4 through 6 are checked against the existing stresses from Column 1.

(TOPSTR(1) and (BOTSTR(1)) to find the correct column to use as the one which lowers the stress for the best attempt to satisfy the limit stress.

If Cycle A is being run, the top (T_{tl}) or bottom (T_{bl}) sections of the array are plates which are specifically designated. They are the bottom plating up to the bilge top, the shear, top and stringer strakes, and the main deck plating. In Cycle B, the plates are the top plates which would buckle and the bottom plates which would buckle. During Cycle B, subroutine (BUK.) is called to find which plates, if any, would buckle for use in the linear program. The second time it is called to handle a case when the limiting stress is satisfied, but some plates still buckle.

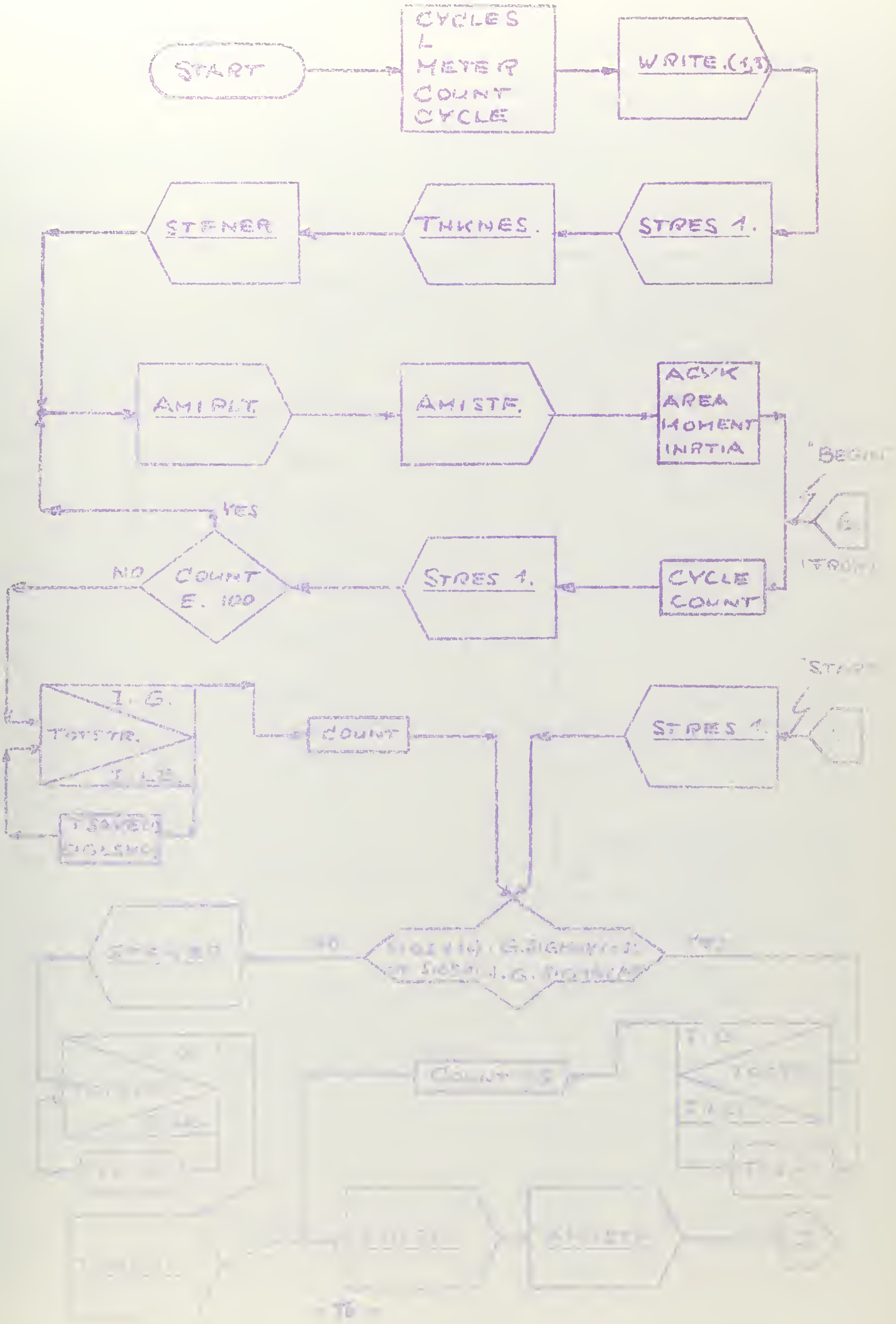
Since Cycle A and Cycle B are independent, the information gained from Cycle A must be stored while Cycle B is run. Upon completion of Cycle B, the results of both A and B are printed for the designer to make a decision on which set of thicknesses should be used as the initial set in Cycle 2. If the design process is to be terminated, subroutine (END.) is called for final print out of the design. For recycling, all necessary quantities are initialized and control is transferred back to the refining subcycle for further lateral instability calculation.

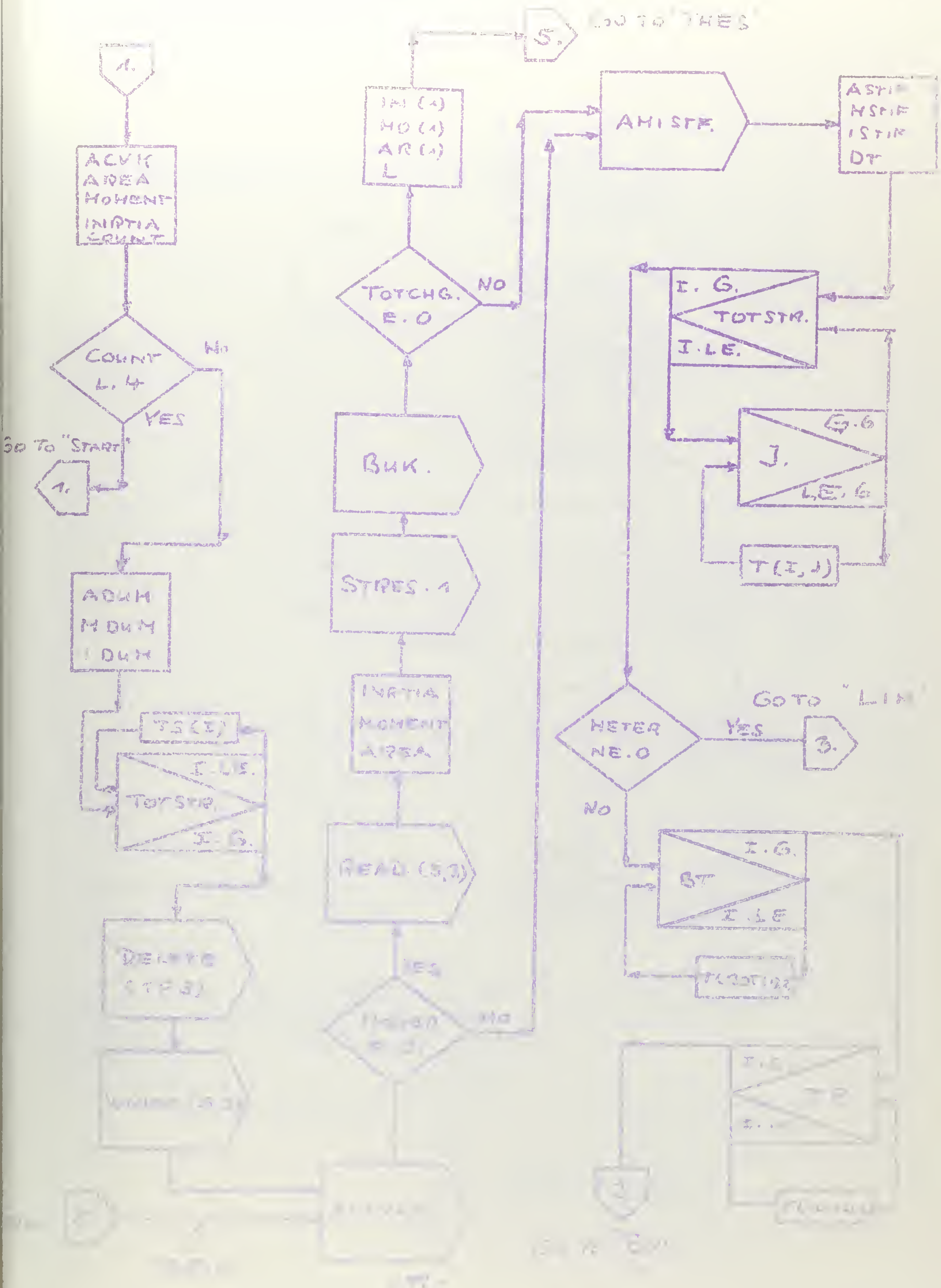
[illegible]

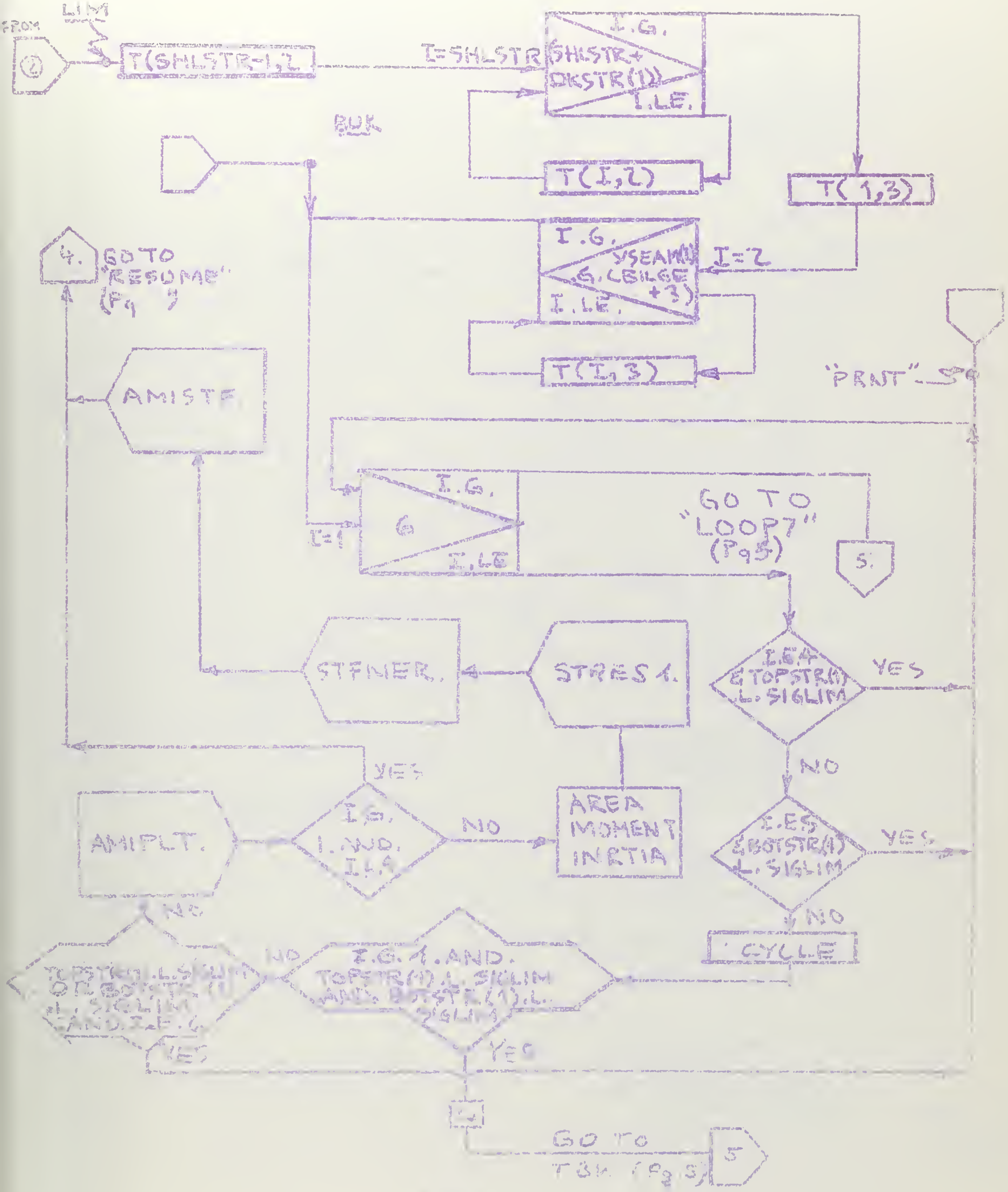
[illegible]	[illegible]
AREA	Current total area of all members
AREA1	Total area resulting from cycle A
AREA2	Total area resulting from cycle B
AR(I)	Area of plates in each column of T(I,J).
ASTIF	Temporary storage of stiffener areas.
BDIf1	Maximum difference between required and actual plate buckling stress in cycle A.
BDIf2	Maximum difference between required and actual plate buckling stressin cycle B.
BOTSTR(I)	Bending stress on bottom fibers after completion of the refining sub-cycle.
COUNT	A counting device to trigger certain operations.
CYCLE	A count of the desired column in T(I,J).
CYCLES	The current man cycle of iteration.
DEF1	Current deficiency in top stress
DEF2	Current deficiency in bottom stress
DET	A determinant in this linear program.
DT	Small increment in thickness of plates at designated locations for linear program.
INERT1	Total moment of inertia at end of cycle A.
INERT2	Total moment of inertia at end of cycle B.
INRT1A	Current total moment of inertia of cross section.
IN(I)	Moment of inertia of each column in T(I,J).
ISTIF	Temporary storage of stiffener inertias.

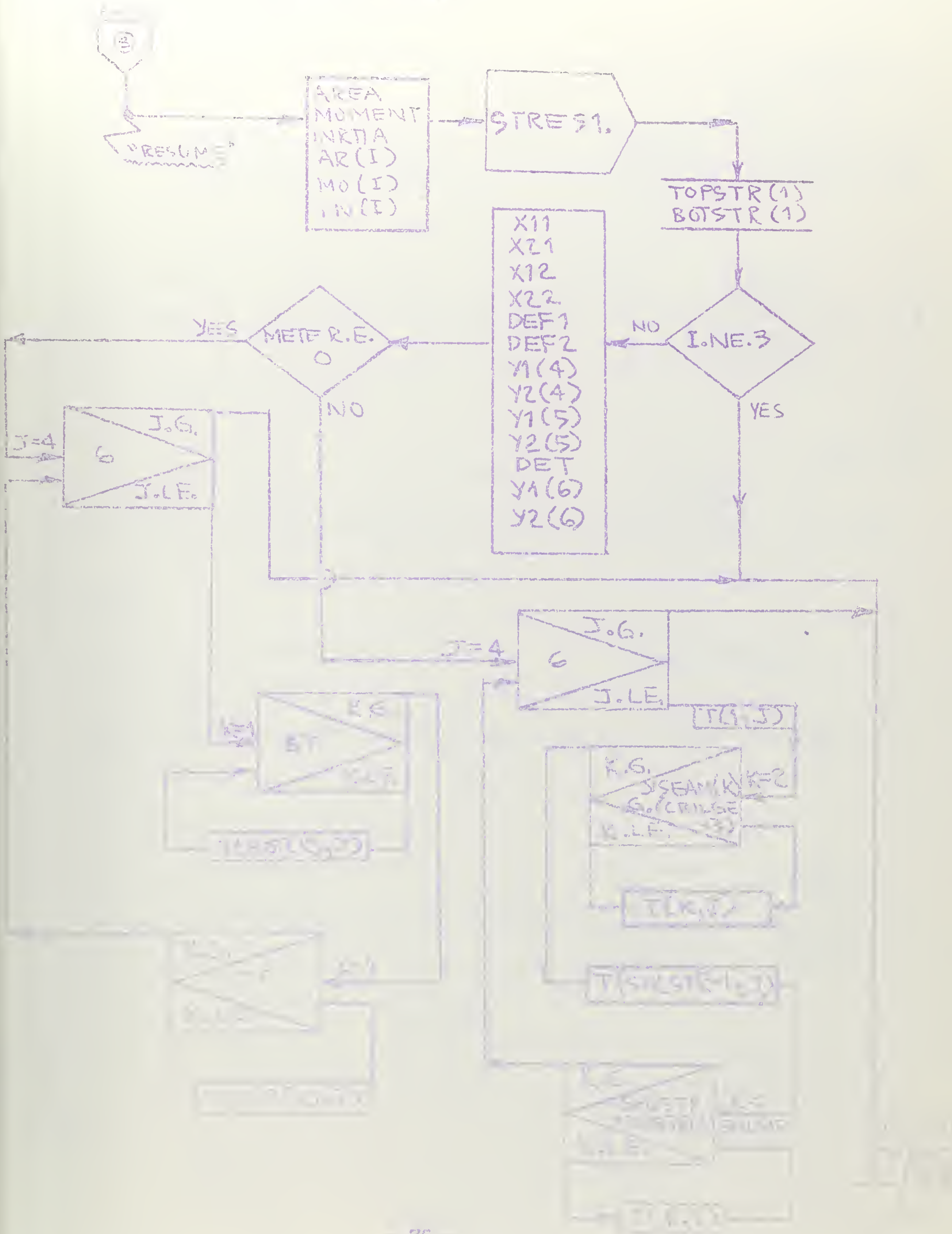
IMD1F1	Deficiency in primary bending stress at end of cycle A.
IMD1F2	Deficiency in primary bending stress at end of cycle B.
METER	A counting device showing whether cycle A or B is running.
MODDK	Section modulus to deck in cycle A.
MODDK1	Section modulus to deck in cycle B.
MODDKL	Section modulus to keel in cycle A.
MODKL1	Section modulus to keel in cycle B.
MOMENT	Current total moment of cross section.
MO(I)	Total moment of each column in T(I,J).
MOM1	Total moment at end of cycle A.
MOM2	Total moment at end of cycle B.
S1GS1(I)	Stress on each plate from cycle B.
S1G1SV(I)	Stress on each plate from cycle A.
S1GLSV(I)	Initial stress on each plate in each main cycle.
STOP1	Trigger to act upon designer's decision.
TL1M(I)	The column of T(I,J) used in cycle A.
TOPSTR(I)	The bending stress on the top fiber upon completion of the refining sub-cycles.
TSAVE(I)	The initial thicknesses for cycle A.
TS(I)	The initial thicknesses saved for cycle B.
X_{11} X_{12} X_{21} X_{22}	Coefficients of the restraint matrix in the linear program.

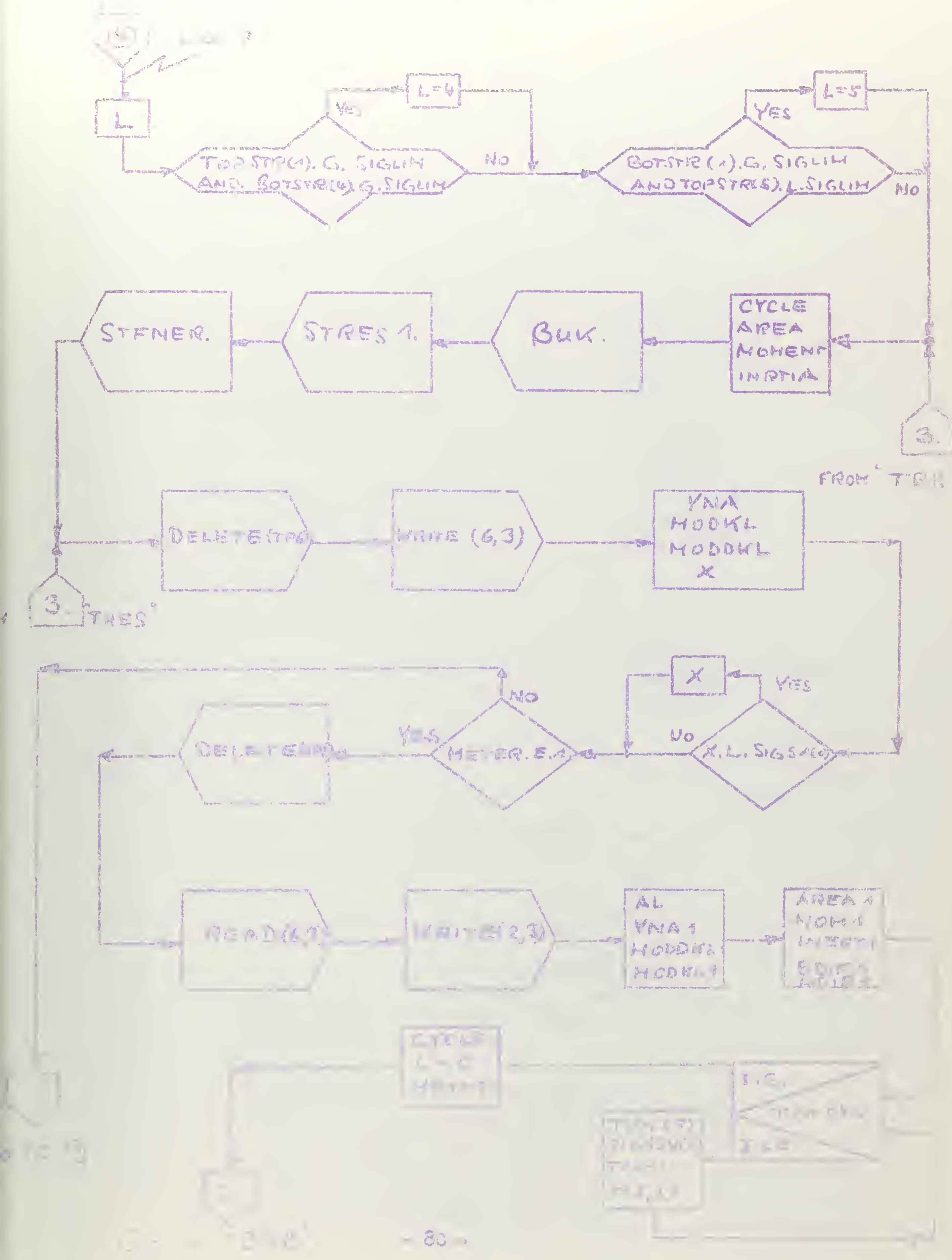
Y1(4)	Actual increase in thickness of the top fibers in column 4.
Y2(4)	Actual increase in thickness of the bottom fibers in column 4.
Y1(5)	Actual increase in thickness of the top fibers in column 5.
Y2(5)	Actual increase in thickness of the bottom fibers in column 5.
Y1(6)	Actual increase in thickness of the top fibers in column 6.
Y2(6)	Actual increase in thickness of the bottom fibers in column 6.
YNA	The neutral axis of the cross section at the end of each cycle.


START
CYCLES
L
METER
COUNT
CYCLE
WRITE (43)
STRES 1.
THKNES.
STENER
AMIPLT.
AMISTF.
ACVK
AREA
MOMENT
INRTIA
"BEGIN"
6.
(FROM)
CYCLE
COUNT
STRES 1.
COUNT
E. 100
YES
NO
I. G.
TOVSTR.
COUNT
"START"
STRES 1.
NO
YES
COUNT

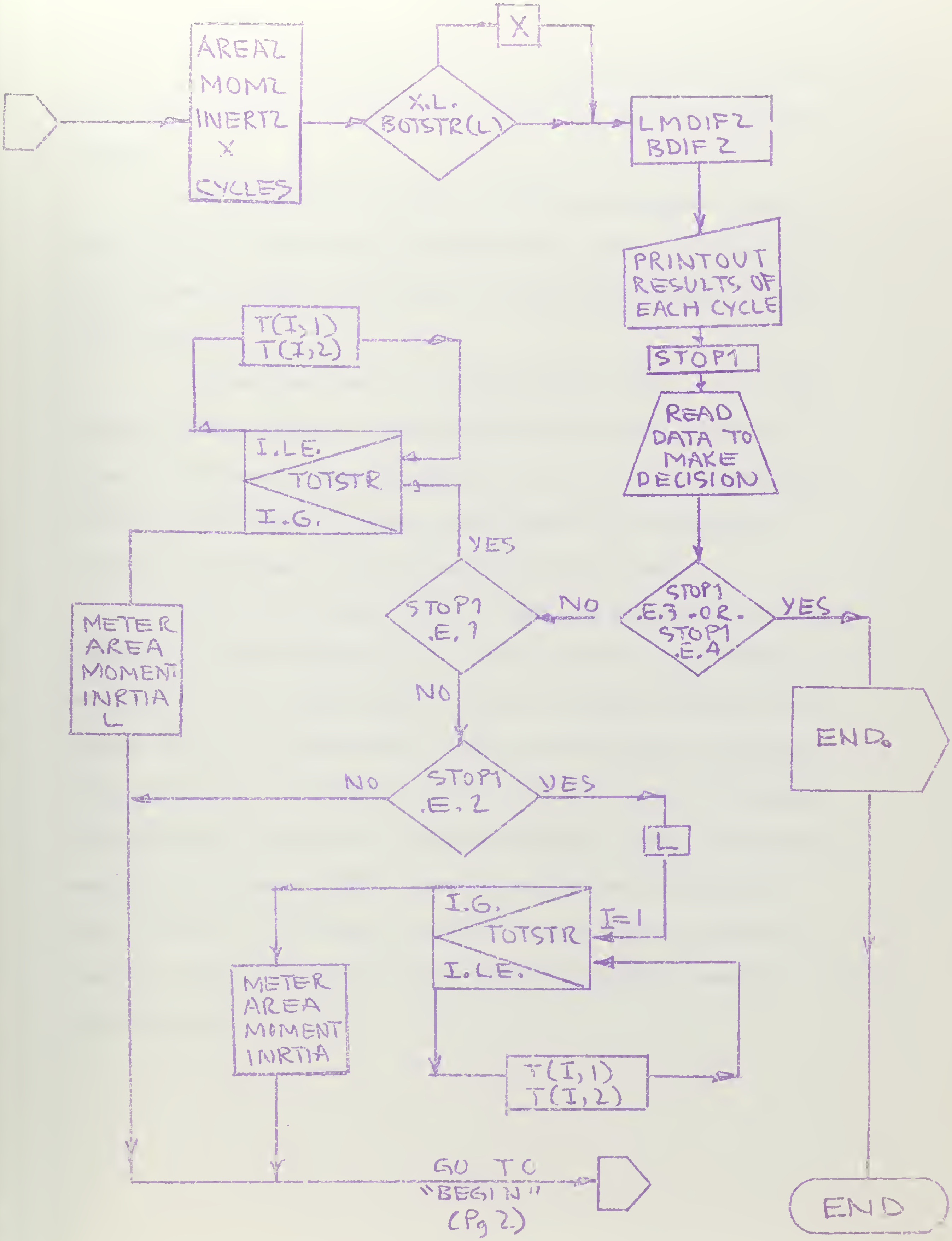

1.
ACUK
AREA
MOMENT
INRTIA
COUNT
COUNT
L. 4
No
YES
Go To "START"
1.
ADUM
MDUM
IDUM
TS(I)
I. LE.
TOT STR.
I. G.
DELETE
(TPS)
IM (1)
MO (1)
AR (1)
L
5.
GO TO 'THES'
TOTCHG.
E. O
NO
BUK.
STRES. 1
INRTIA
MOMENT
AREA
READ (5,3)
YES
NO
AHI STR.
ASTIF
MSNF
ISTIF
DT
I. G.
TOT STR.
I. LE.
G. 6
J.
LE. 6
T (I, J)
METER
NE. O
YES
GO TO 'LIN'
3.
NO
I. G.
BT
I. LE
I. G.
I. LE


FROM
LIM
②
T(SHLSTR-1,2)
I=SHLSTR
I.G.
SHLSTR+
DKSTR(1)
I.LE.
T(I,2)
T(1,3)
BUK
I.G.
YSEAM(1)
.G.LBILGE
+3)
I.LE.
I=2
T(I,3)
4.
GO TO
"RESUME"
(Pg)
AMISTF
"PRNT"
I=1
I.G.
6
I.LE
GO TO
"LOOP7"
(Pg5)
5.
STFNER.
STRES1.
I.E.4
&TOPSTR(1)
.L.SIGLIM
YES
NO
AREA
MOMENT
INERTIA
YES
I.G.
1.AND.
I.L.4
NO
AMIPLT.
I.E.5
&BOTSTR(1)
.L.SIGLIM
YES
NO
CYCLE
NO
TOPSTR(1).L.SIGLIM
OR.BOTSTR(1)
.L.SIGLIM
AND.I.E.6
NO
I.G.4.AND.
TOPSTR(1).L.SIGLIM
AND.BOTSTR(1).L.
SIGLIM
YES
YES
GO TO
T3K (Pg3)
5

2
PRESUME
AREA
MOMENT
INRTIA
AR(I)
MO(I)
IN(I)
STRESS1.
TOPSTR(1)
BOTSTR(1)
I.NE.3
NO
YES
X11
X21
X12
X22
DEF1
DEF2
Y1(4)
Y2(4)
Y1(5)
Y2(5)
DET
Y1(6)
Y2(6)
METER.E.
0
YES
NO
J=4
6
J.G.
J.LE.
J=4
6
J.G.
J.LE.
T(1,J)
K.G.
K.LE.
K=2
T(K,J)
K=1
K.G.
K.LE.
TSTR(K,J)


L
YES
L=4
TOPSTR(1).G.SIGLIM
AND. BOTSTR(4).G.SIGLIM
NO
YES
L=5
BOTSTR(1).G.SIGLIM
AND TOPSTR(5).L.SIGLIM
NO
STFNER.
STRES 1.
BUK.
CYCLE
AREA
MOMENT
INRTIA
3.
FROM 'TERR
DELETE(TPG)
WRITE (6,3)
YNA
MODKL
MODDKL
X
3.
TRES'
X
YES
NO
NO
YES
DELETE(RD)
METER.E.1
X.L.SIGS(10)
READ(6,1)
WRITE(2,3)
AL
YNA 1
MODDK2
MODKA1
AREA 1
MOM 1
INERT 1
E.G.
TO 'FG'

CYC (CONT)


AREA2
MOM2
INERT2
X
CYCLES
X
X.L.
BOTSTR(L)
LMDIF2
BDIF2
PRINTOUT RESULTS OF EACH CYCLE
STOP1
READ DATA TO MAKE DECISION
STOP1 .E.3 .OR. STOP1 .E.4
YES
END.
T(I,1)
T(I,2)
I.LE.
TOTSTR
I.G.
YES
STOP1 .E.1
NO
NO
METER AREA MOMENT INRTIA L
NO
STOP1 .E.2
YES
L
I.G.
TOTSTR
I.LE.
I=1
METER AREA MOMENT INRTIA
T(I,1)
T(I,2)
GO TO "BEGIN" (Pg 2)
END

BUK.

This subroutine tests the plate thicknesses obtained from local lateral loading for instability under the applied compressive stresses.

The subroutine is called by (CYC.) and consists of two main parts: one that tests the longitudinally framed sections for buckling and the other that tests the transversely framed sections for buckling.

For sections that are longitudinally framed, the critical buckling stress, SIGBUL, is determined for each panel by Bryan's Formula. The current panel thicknesses are used in the formula, and when two plate seams lie between longitudinals, the subroutine selects the thickness of the thinner plate to be used.

The actual primary stress, SIGBKL, is calculated as the stress on the point of each panel furthest from the neutral axis. When SIGBKL is less than SIGBUL, the panel thickness remains as the current value TB. When SIGBKL is greater than SIGBUL, the current panel thickness is increased to the mean value between the current panel thickness, TB, and the required thickness, TL(J), the thickness required to withstand SIGBKL. When SIGBKL has been decreased to within 100 p.s.i. of SIGBUL, the panel is considered to satisfy the buckling stress. The factor of 100 is used to prevent excessive cycling in the computer.

For sections that are transversely framed, the primary stress acting on a panel is calculated by the subroutine (MAXSTR.), which determines the maximum compressive stress, SIGBKT, acting on each transversely framed panel. The critical buckling stress, SIGBUT, is calculated by Montgomerie's Formula. SIGBUT is calculated for each plate comprising the panel, assuming the panel consists only of that plate thickness. Thus each current plate thickness within the transverse panel is tested for buckling. If SIGBKT is less than SIGBUT, the plate thicknesses remain as the current thickness T(I,L). If SIGBKT is greater than SIGBUT, the plate thickness is increased to the mean value between the current thickness T(I,L), and the required thickness TL(J), the thickness required to withstand SIGBKT. When SIGBKT is within 100 p.s.i. of SIGBUL, the panel satisfies buckling.

(BUK.) is executed at three points in the program: at the beginning of Cycle B, and at the end of Cycles A and B. At the beginning of Cycle B, (BUK.) determines which plate panels buckle, so that the linear program in (CYC.) knows which panel thicknesses to change. (BUK.) is executed at the end of Cycles A and B to determine if any plates buckle after being changed by the linear program.

Four possible situations exist when (BUK.) is executed at the end of Cycle A and B.

I. Limiting stress satisfied and no plates buckle.
II. Limiting stress not satisfied and no plates buckle.
III. Limiting stress not satisfied and plates buckle.
IV. Limiting stress satisfied and plates buckle.

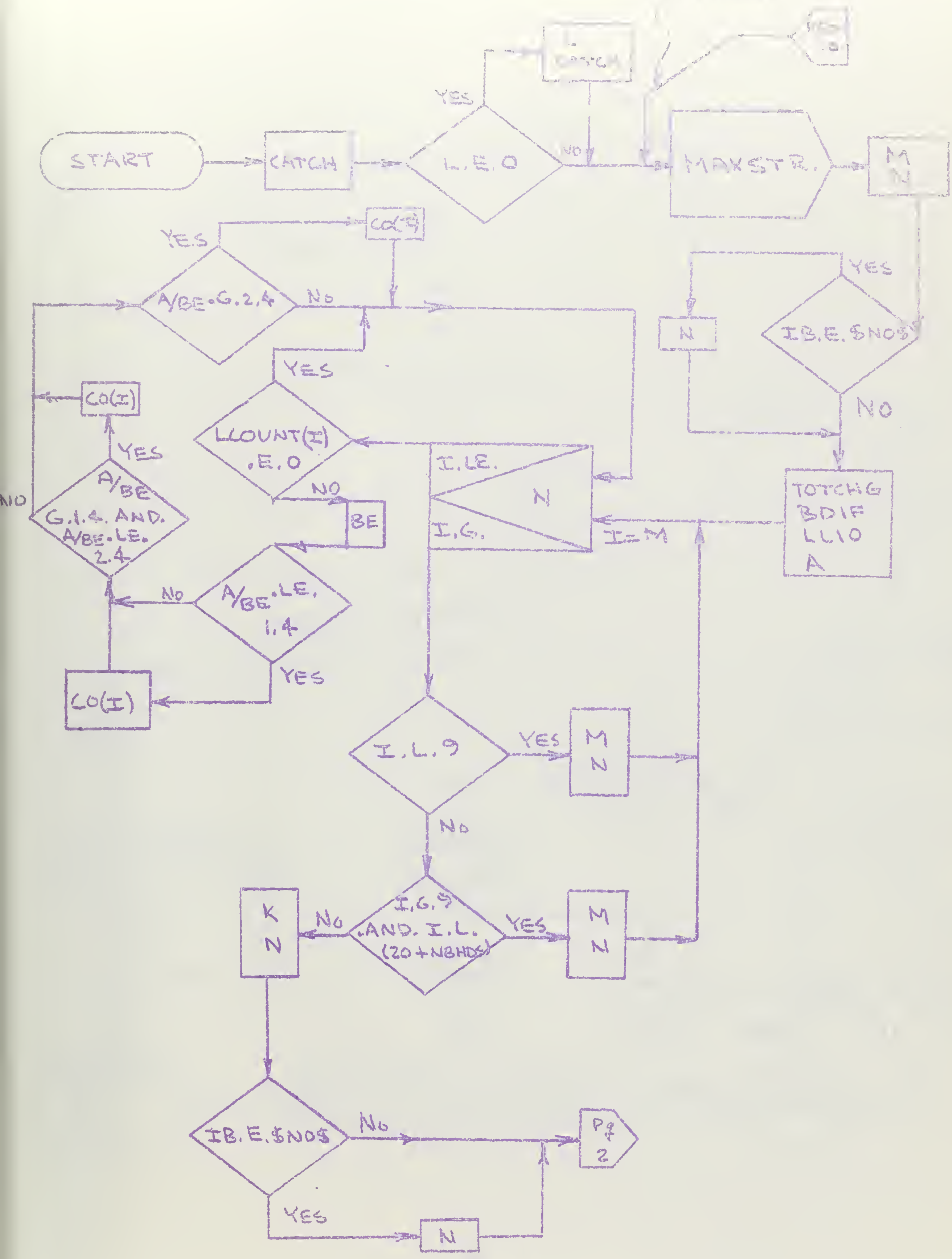
In cases I and II, the thicknesses entering (BUK.) are returned to (CYC.). In case III, (BUK.) increases the thicknesses of the plates that buckle in the manner described previously, and the thicknesses are returned to (CYC.). In case IV, (BUK.) will cycle until all plates satisfy the buckling stress. The thicknesses of the panels that buckle are increased in the manner previously described. The new cross-sectional area properties of longitudinal continuous members are calculated by (AMIPLT.) and (AMISTF.), and the new stress distribution is determined by (STRES1.). New stiffener scantlings are calculated by (STFNER.) and then (THKNES.) is executed to keep the plate thicknesses up-to-date with the new stress schedule. The new stress distribution and panel thicknesses are returned to the beginning of (BUK.), where re-cycling occurs. Only after all plate thickensses meet the instability requirements will cycling cease, and control returns to (CYC.). For all cases, when the panel thicknesses are returned to (CYC.), they are printed out under the headings:

"BENDING GOVERNS" for Cycle A and

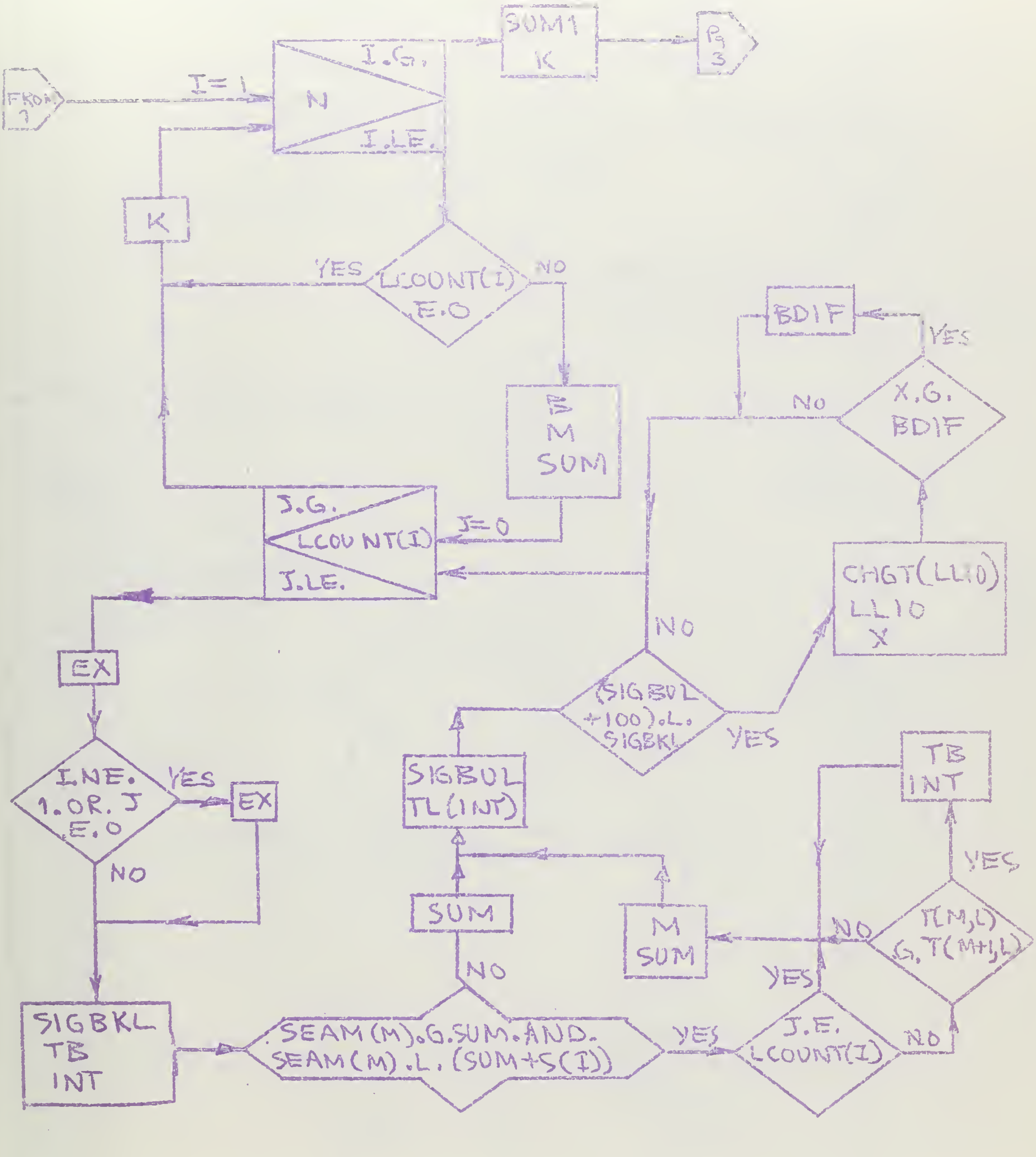
"BUCKLING GOVERNS for Cycle B.

LIST OF SYMBOLS CALCULATED IN (SUB.)

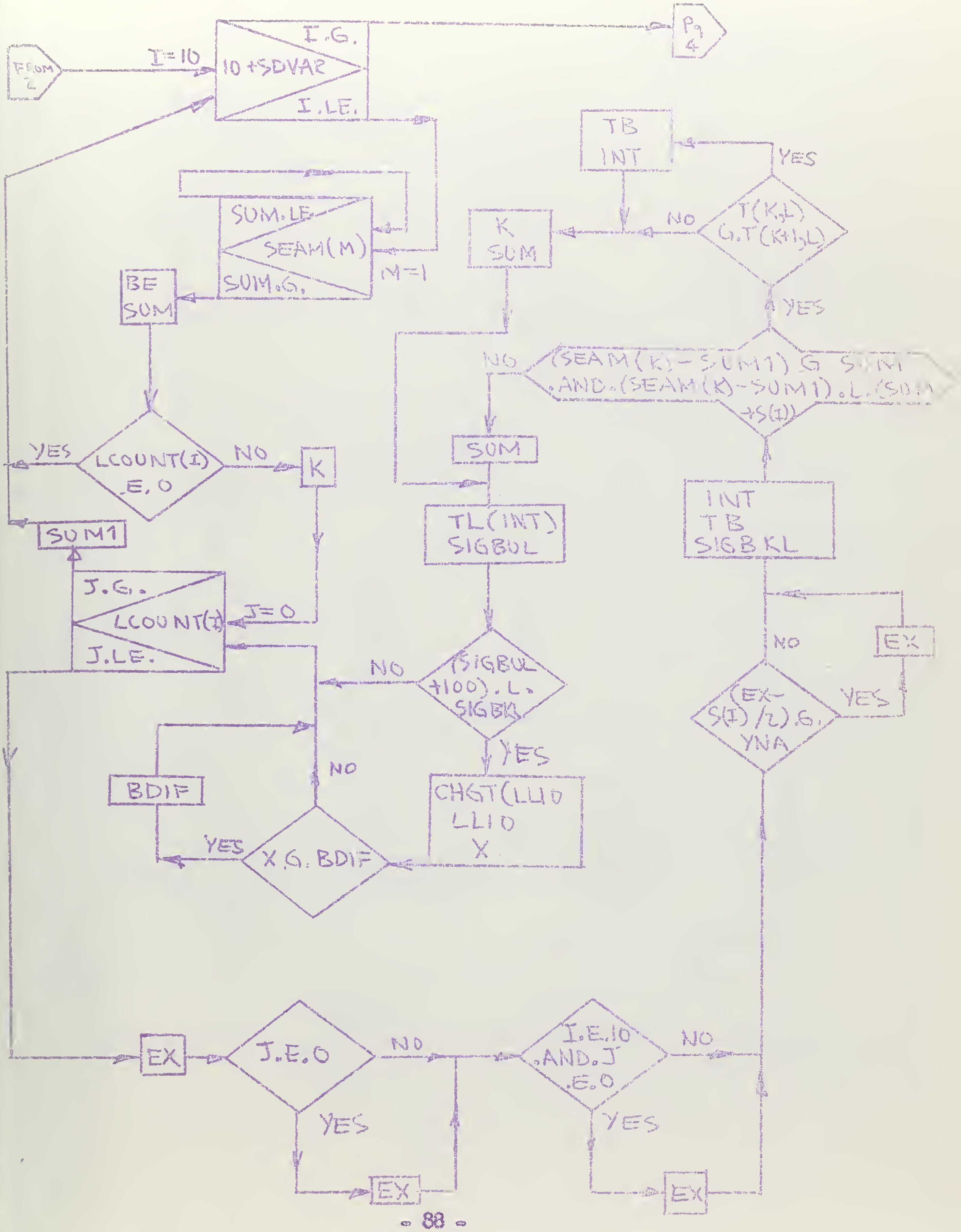
A	Dimension of a plate panel in line with the load.
BDIF	Maximum difference between the actual and critical buckling stress acting on a panel.
BE	Dimension of a plate panel perpendicular to the load.
BOT(M)	The number of a plate which is located below the neutral axis and buckles.
BT	The total number of plates which are located below the neutral axis and buckle.
CEG(I)	The number of a plate that buckles.
CO(I)	The constant "K" used in Bryan's Formula which is a function of the edge restraint conditions and the boundary conditions.
SIGBKL	Applied primary stress acting on a longitudinally framed panel.
SIGBUL	Critical buckling stress determined from Bryan's Formula.
SIGBUT	Critical buckling stress determined from Montgomerie's Formula.
TB	Actual thickness of a longitudinally framed panel.
TL(I)	Required thickness of a longitudinally or transversely framed panel to withstand compressive loading.
TOP(K)	The number of a plate which is located above the neutral axis and buckles.
TOTCHG	Total number of plates that buckle.
TP	The total number of plates which are located above the neutral axis and buckle.


START
CATCH
YES
I
CATCH
L.E.O
NO
MAXSTR.
M
N
YES
IB.E.NOS
NO
N
TOTCHG
BDIF
LL10
A
YES
CO(I)
A/BE.G.2.4
No
NO
YES
LLOUNT(I)
.E.O
NO
BE
I.LE.
N
I.G.
I=M
CO(I)
YES
A/BE
G.1.4. AND.
A/BE.LE.
2.4
No
A/BE.LE.
1.4
YES
CO(I)
I.L.9
YES
M
N
No
I.G.9
.AND. I.L.
(20+NBHDS)
YES
M
N
No
K
N
IB.E.NO
No
Pg
2
YES
N

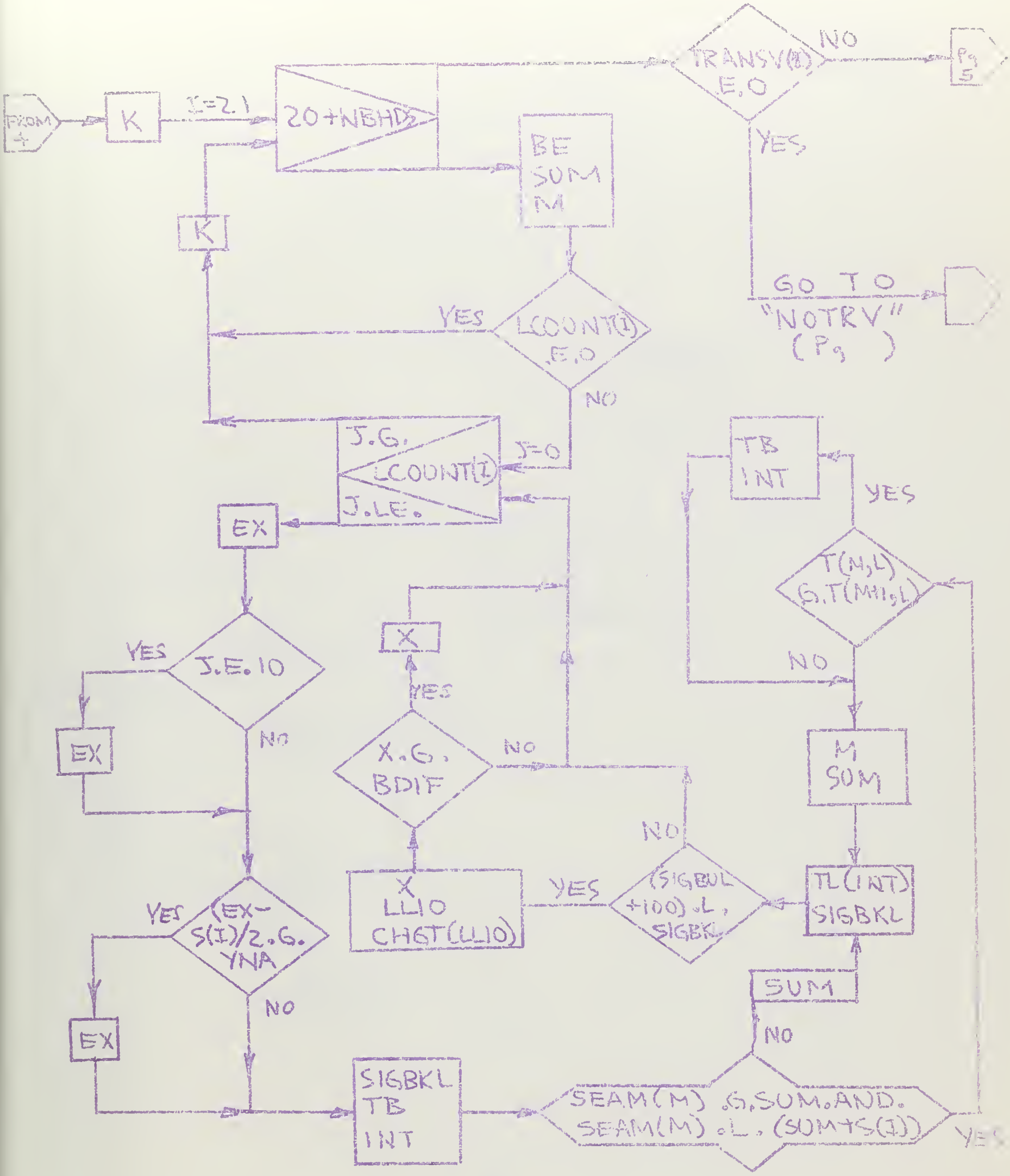
BUK. (CONT)


FROM 7
I=1
I.G.
N
I.LE.
SUM1
K
Pg 3
K
YES
LCOUNT(I)
E.O
NO
B
M
SUM
J.G.
LCOUNT(I)
J.LE.
J=0
BDIF
YES
NO
X.G.
BDIF
CHGT(LL10)
LL10
X
NO
(SIGBUL
+100).L.
SIGBKL
YES
EX
I.NE.
1.OR.J
E.O
YES
EX
NO
SIGBUL
TL(INT)
TB
INT
YES
SUM
M
SUM
NO
T(M,L)
G.T(M+1,L)
NO
YES
SIGBKL
TB
INT
SEAM(M).G.SUM.AND.
SEAM(M).L.(SUM+S(I))
YES
J.E.
LCOUNT(I)
NO

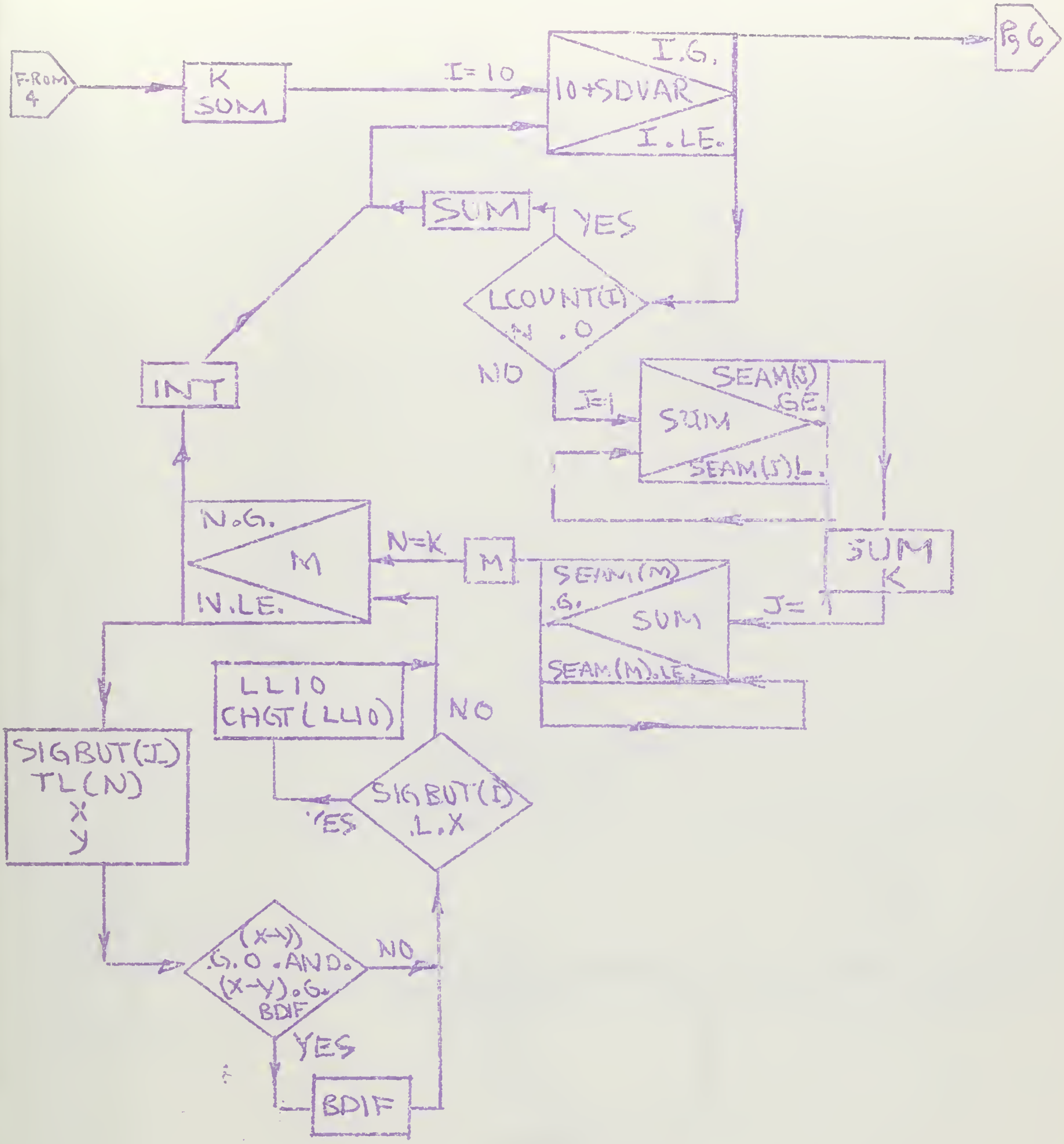
BUK. (CONT)


FROM 2
I=10
I.G.
10 +SDVAR
I.LE.
Pg 4
SUM.LE.
SEAM(M)
SUM.G.
M=1
BE SUM
LCOUNT(I) .E. 0
YES
NO
K
SUM1
J.G.
LCOUNT(I)
J.LE.
J=0
BDIF
YES
NO
X.G. BDIF
TB INT
YES
T(K,L) G.T(K+1,L)
NO
K SUM
YES
(SEAM(K)-SUM1) G SUM .AND.(SEAM(K)-SUM1).L.(SUM +S(I))
NO
SUM
TL(INT) SIGBOL
(SIGBOL +100).L. SIGBKL
NO
YES
CHGT(LLID LLID X
INT TB SIGBKL
NO
EX
(EX- S(I)/2).G. YNA
YES
EX
J.E.0
NO
YES
EX
I.E.10 .AND.J .E.0
NO
YES
EX

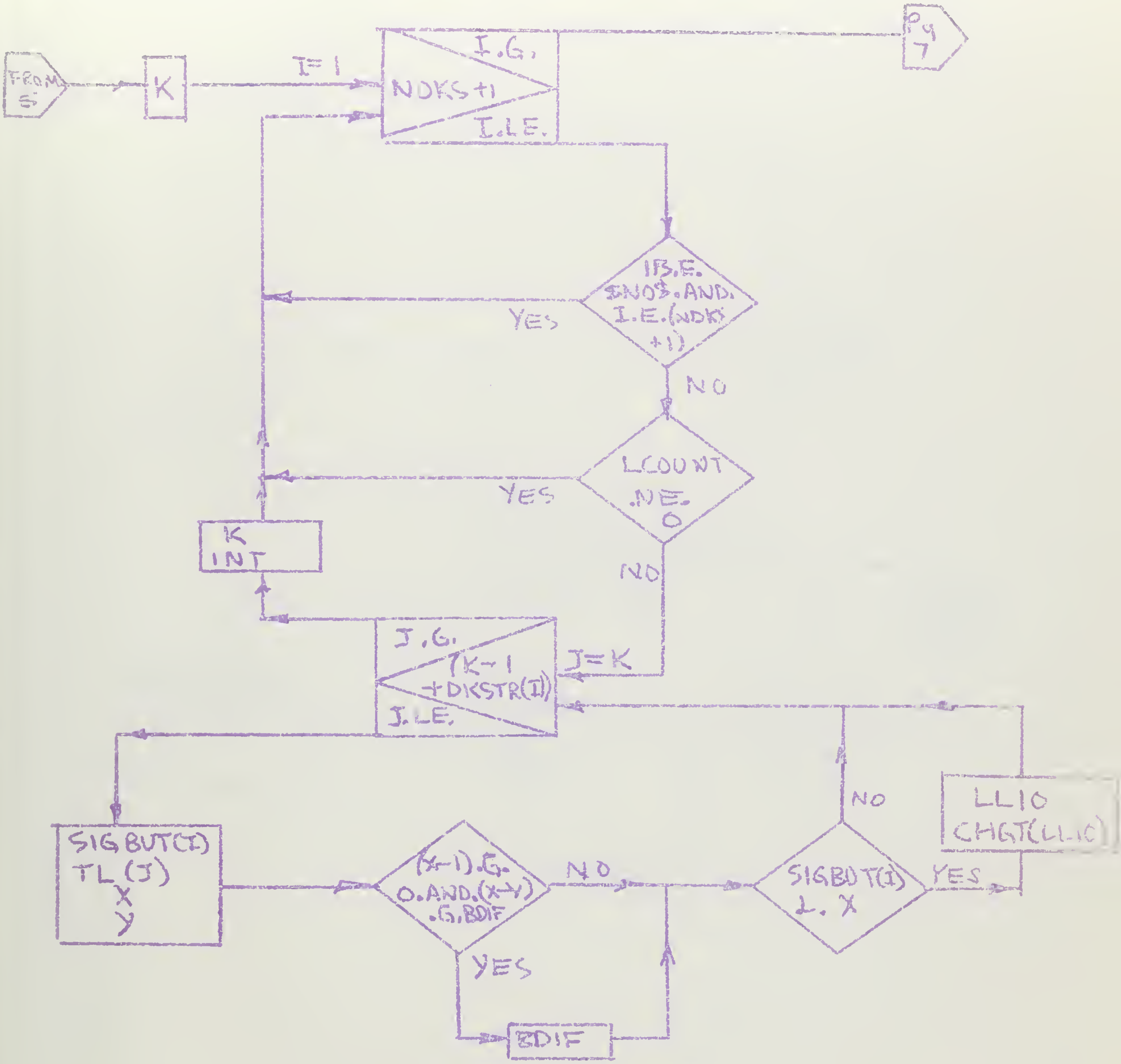
BUK. (CONT)


FROM 4
K
I=2,1
20+NBHD
TRANSV(I) .E.0
NO
Pg 5
YES
GO TO "NOTRV" (Pg)
BE SUM M
K
YES
LCOUNT(I) .E.0
NO
J=0
J.G. LCOUNT(I) J.LE.
EX
TB INT
YES
T(M,L) .G.T(M+1,L)
NO
YES
J.E.10
NO
EX
X
YES
X.G. BDIF
NO
M SUM
NO
X LL10 CHGT(LL10)
YES
(SIGBUL +100).L. SIGBKL
TL(INT) SIGBKL
YES
(EX-S(I)/2.G. YNA
NO
SUM
NO
EX
SIGBKL TB INT
SEAM(M) .G.SUM.AND. SEAM(M) .L. (SUM+S(I))
YES

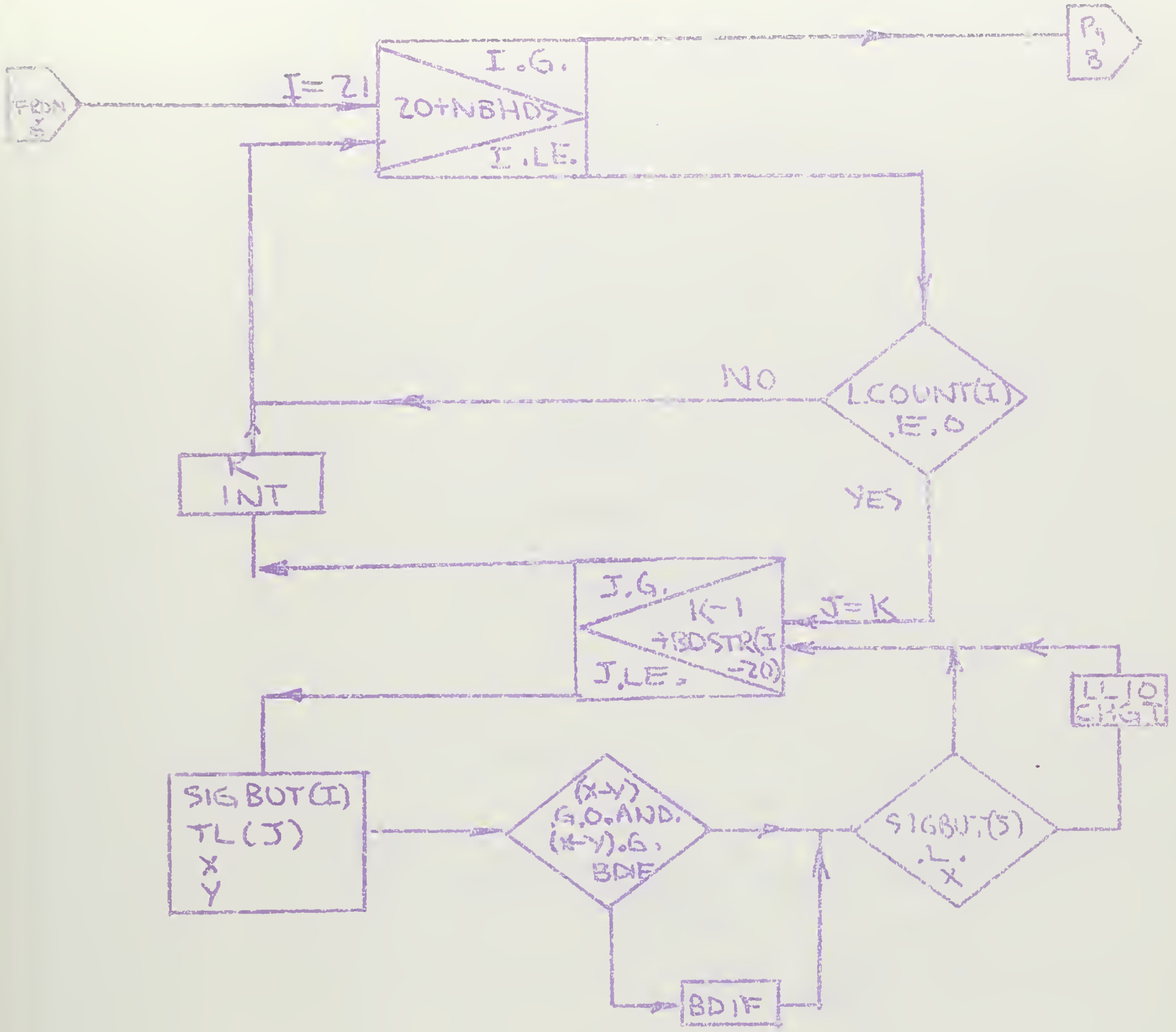
BUK. (CONT)


FROM 4
K
SUM
I=10
I.G.
10+SDVAR
I.LE.
Pg 6
SUM
YES
LCOUNT(I)
.N .0
NO
J=1
SEAM(J)
.GE.
SUM
SEAM(J).L.
INT
N.G.
M
N.LE.
N=K
M
SEAM(M)
.G.
SUM
SEAM(M).LE.
J=1
SUM
K
LL10
CHGT(LL10)
NO
SIGBUT(I)
TL(N)
X
Y
SIGBUT(I)
.L.X
YES
(X-Y)
.G.0 .AND.
(X-Y).G.
BDIF
NO
YES
BDIF

BUK. (CONT)

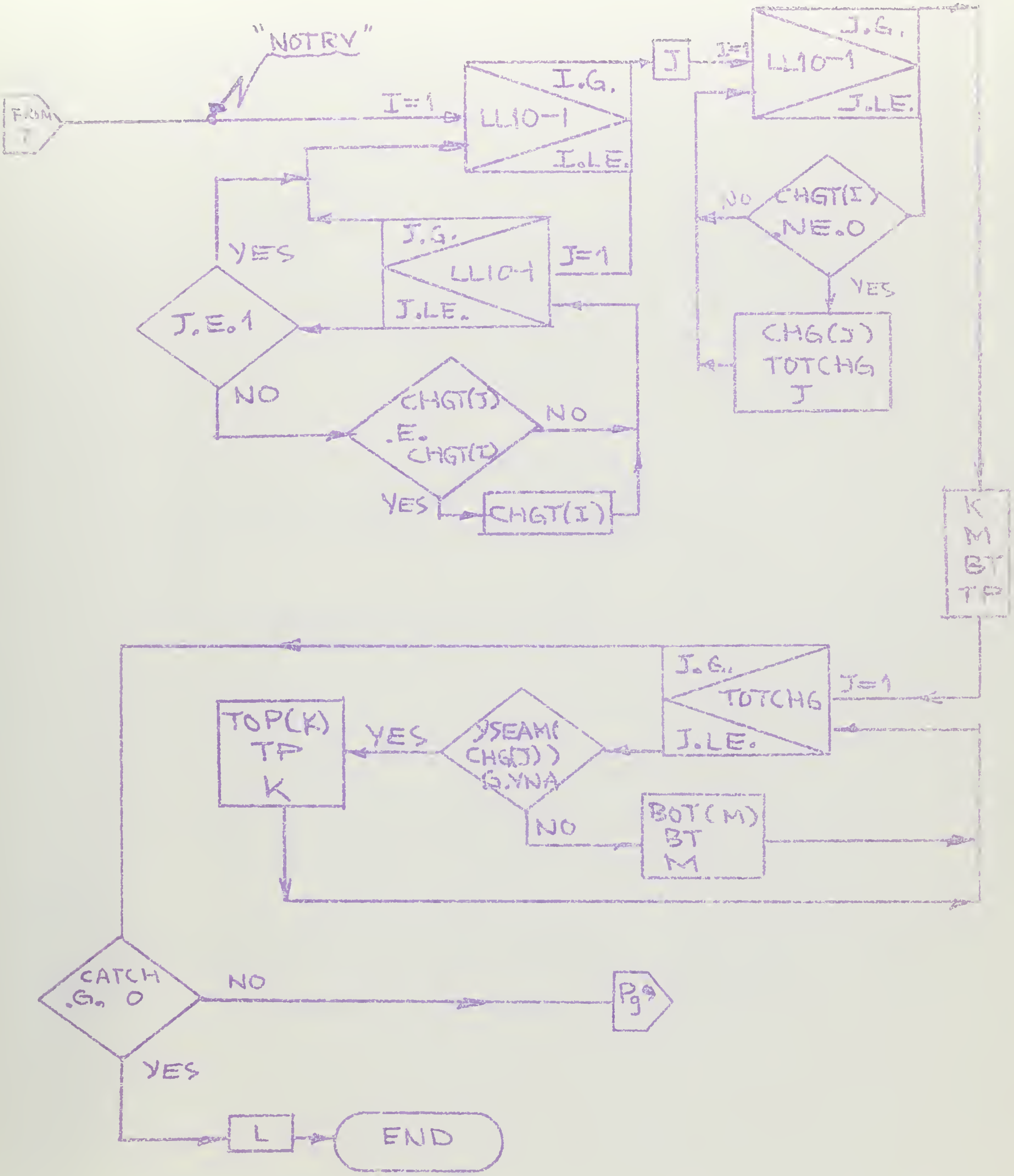

FROM 5
K
I=1
I.G.
NDKS+1
I.LE.
Pg 7
IB.E.
NO.AND.
I.E.(NDKS
+1)
YES
NO
LCOUNT
.NE.
0
YES
NO
K
INT
J.G.
(K-1
+DKSTR(I))
J.LE.
J=K
SIG BUT(I)
TL(J)
X
Y
(X-1).G.
0.AND.(X-Y)
.G.BDIF
NO
YES
BDIF
SIGBUT(I)
L. X
NO
YES
LLIO
CHGT(LLIO)

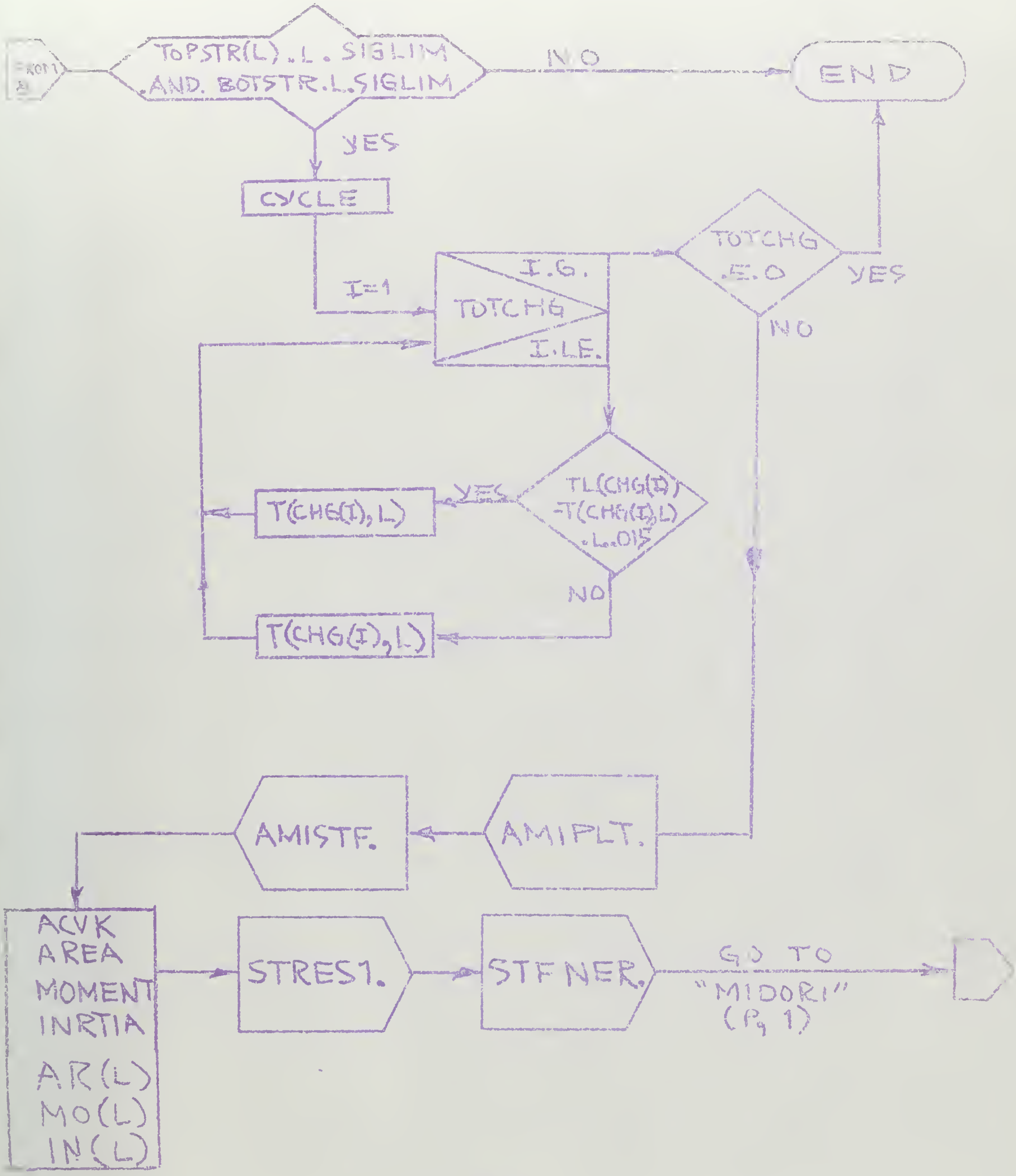
BUK (cont)


FROM
3
I=21
I.G.
20+NBHDS
I.LE.
P4
B
NO
I.COUNT(I)
.E.0
YES
K
INT
J.G.
K-1
+BDSTR(I
-20)
J.LE.
J=K
LL10
CHG.1
SIGBUT(I)
TL(J)
X
Y
(X-Y)
.G.O.AND.
(X-Y).G.
BDIF
SIGBUT(J)
.L.
X
BDIF

8

BUK. (CONT.)


FROM 7
"NOTRY"
I=1
I.G.
LL10-1
I.LE.
J
J=1
J.G.
LL10-1
J.LE.
NO
CHGT(I)
.NE.0
YES
CHG(J)
TOTCHG
J
J.G.
LL10-1
J.LE.
J=1
YES
J.E.1
NO
CHGT(J)
.E.
CHGT(I)
NO
YES
CHGT(I)
K
M
BT
TP
J.G.
TOTCHG
J.LE.
J=1
TOP(K)
TP
K
YES
YSEAM(
CHG(J))
.G.YNA
NO
BOT(M)
BT
M
CATCH
.G. 0
NO
Pg9
YES
L
END


FROM
A
TOPSTR(L) .L. SIGLIM
.AND. BOTSTR.L.SIGLIM
NO
END
YES
CYCLE
I=1
I.G.
TOTCHG
I.LE.
TOTCHG
.E.O
YES
NO
TL(CHG(I))
-T(CHG(I),L)
.L..015
YES
T(CHG(I),L)
NO
T(CHG(I),L)
AMISTF.
AMIPLT.
ACVK
AREA
MOMENT
INRTIA
AR(L)
MO(L)
IN(L)
STRES1.
STFNER.
GO TO
"MIDORI"
(Pg 1)

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